Green Mark 2021

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NEW NON-RESIDENTIAL BUILDINGS TECHNICAL GUIDE

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Maintainability Technical Reference (Non-residential Building) Revision Log

S/N	Brief description of changes	Effective date
01	First issue (Version 1.0)	01 Nov 2021
02	Second issue with minor updates (Version 1.1)	01 Nov 2021
03	Third issue with minor updates (Version 1.2)	01 Nov 2021
04	Fourth issue (Version 2.0) • Editorial changes across the framework for improved clarity. • Addition of criteria/ revision to existing criteria i) 2.3.3b (50mm raised partition) ii) 2.3.6c (open ceiling) iii) 3.1.2a (permanent sleeve to mount davit arm) iv) 3.6.2b (weatherproof fire-rated material) v) 5.1.1a (20m radius water points) vi) 5.2.1aii (shallow water body) • Deletion of former criteria i) 1.4.1a (efflorescence) ii) 2.2 (walls and partitions) iii) 2.4.1d (basement- negative side waterproofing) iv) 3.5.1a (cleaning eyes with viewing panel) v) 3.6.1a (access to fire detectors) vi) 4.1.1a (access to light fixtures) vii) 5.6.1c (water absorption rate of engineered wood)	01 Jan 2024
05	Fifth issue with minor updates (Version 2.1)	01 Jan 2024

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CHAPTER 1: PRINCIPLES & ASSESSMENT APPROACH

Principles

1. Design for Maintainability

Maintainability is a measure of the ease and ability with which maintenance actions or activities can be carried out. A lack of maintainability considerations at the onset of project often creates avoidable maintenance demands which can lead to higher upkeep costs and manpower needs.

"*Design for Maintainability (DfM)*" encompasses the specific measures taken during planning and design to minimise the occurrence of building defects and the expenditure of man-hours and materials to fulfil the maintenance needs in the building lifecycle.

Four important principles are identified, which can be coined as the F.A.M.E principle:

(a) *Forecast maintenance* – Designers should understand the impact of their designs and the expected downstream maintenance works, thereby making necessary upstream design provisions.

(b) *Access for maintenance* – Designers should give due considerations for all areas requiring access for inspection and maintenance, thereby making necessary design provisions.

(c) *Minimise defects* - Designers should give adequate attention to materials performance and detailing to minimise common and critical defects.

(d) *Enable simple maintenance* – Designers should consciously consider standardisation and prefabricated components to facilitate easy inspection and productive maintenance.

2. Maintainability Section (NRB)

The Maintainability Section (NRB) highlights the importance of DfM and allows cross-functional stakeholders across the value chain - including developers, designers, and FM practitioners – to understand DfM considerations.

It presents a systematic structure and set of design strategies / solutions to weave in DfM considerations into the project at the onset. The Maintainability Section (NRB) is performance-based, i.e. it is the intent or objective that is most important and needs to be achieved. The design strategies / solutions suggested therein are in no way exhaustive and alternative approaches would be considered so long as the intent is achieved.

It is worth emphasising that when it comes to access for maintenance, care must be taken that it does not require passing through private or tenanted spaces.

Assessment

1. Assessment approach

i. Scope of common areas

The Maintainability Section (NRB) is serves to evaluate a building's maintainability holistically. However, for the purposes of assessment, the focus will be on areas which are either '***common areas'*** ***or*** '***developer-owned'*** spaces. In the context of this assessment, the definition of the 2 spaces are as such:

'***common areas'*** – spaces accessible by the public and often experience high footfall

'***developer owned'*** – spaces which fall within the purview and control of the building's developer / owner

The worked examples within this technical guide can be used as a reference to aid in categorising whether areas should or should be considered for assessment.

ii. Tenant spaces and residential units

The assessment only covers common areas within the project. However, exceptions are made to access for Condenser Units as these are within designer's control.

iii. Systems for Standby or Night-load

For buildings that are served by chiller, VRF systems used for standby or night-load will not be assessed. The Maintainability Section (NRB) does not assess standby systems.

iv. SMART FM

Smart FM solutions presented in the Maintainability Section (NRB) zooms in specifically on those that improve cost effectiveness and manpower efficiency of downstream maintenance regimes, such as:

☑ Predictive maintenance of chiller plant
☒ Using AI for chiller plant energy efficiency optimization

2. Allocation of points

Category 1 (Cat 1)
Assessment: Full points for solutions only with 100% applicability in area of application or number of instances.
Category 2 (Cat 2)
Assessment: **a.** Apportioned points for solutions with 15% to 85% coverage (partial or apportioning) in area of application or number of instances. **b.** Full points for solutions with >85% coverage in area of application or number of instances. **c.** No points for solutions with <15% coverage in area of application or number of instances.

3. Pro-rating of points

The scoring adopts a pro-rating approach for criteria that are not applicable for any particular project, e.g. a project using VRF system will see the points allocated for chiller plant being not applicable and the points will be prorated using the formula below. This allows projects to be evaluated on a fair and equitable basis despite differences in typologies, adopted systems, or scale.

$$Points\ scored\ after\ proration = (Points\ scored) \times \frac{(Total\ number\ of\ points)}{(Total\ number\ of\ points) - (Total\ points\ which\ are\ not\ applicable)}$$

CHAPTER 2: LCC METHODOLOGY

1. Introduction

Life cycle cost (LCC) analysis is a method of economic analysis that includes costs related to procurement, construction, operation, and maintenance over a defined period. The key emphasis of LCC in the Maintainability Section (NRB) is to ascertain the operations and maintenance cost savings of the alternative good practice, especially the saving due to improvement in productivity as well as manpower reduction, over the current industry baseline. To achieve holistic sustainability, it is strongly recommended to integrate life cycle cost approach in the early design stage considering both sustainability and maintainability benefits of the proposed design alternative.

The LCC study for the Maintainability Section (NRB) refers to the methodology set in

- **ISO15686-5: 2017**, Building and constructed assets – Service life planning, part 5, Life-cycle costing.
- **NIST Handbook 135**, Life-cycle Costing Manual by U.S. Department of Commerce, Technology Administration and National Institute of Standards and Technology. Comply with ASTM Standard E917.

2. LCC Analysis Vs Simple Payback Method

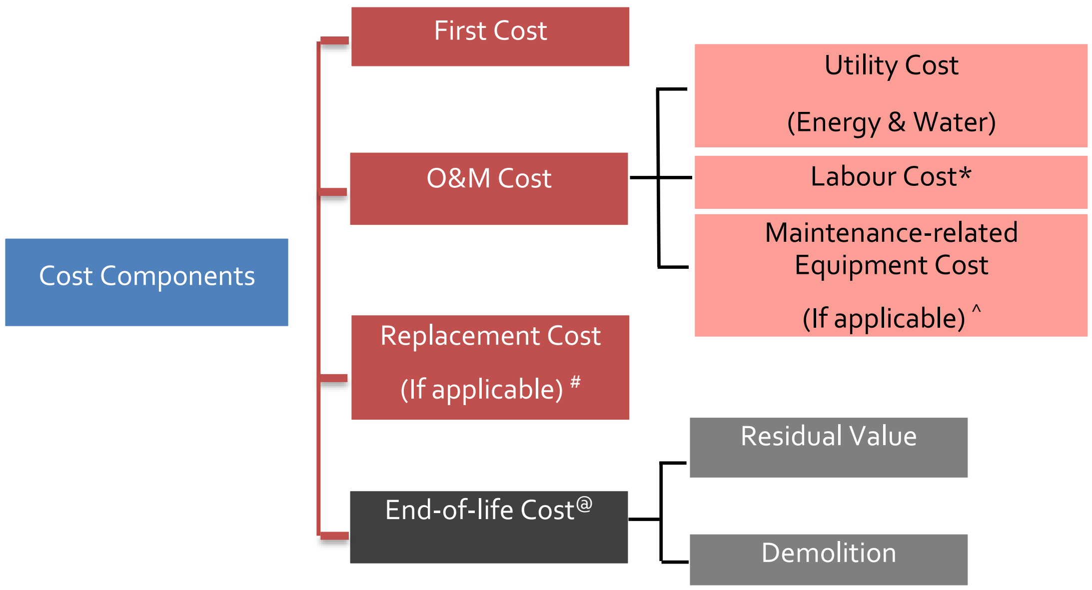
The Maintainability Section (NRB) employs an LCC study to evaluate the design with maintenance in mind. The Maintainability Section (NRB) promotes holistic sustainability in terms of long term economic and social impact through greater cost savings and reduced reliance on manual labour.

While simple payback is a quick way to assess the return on capital investment, it does not consider the total cost of ownership, including the labour intensity of operations and maintenance. Simple payback is widely used to assess the systems associated with energy consumption but less prevalent for passive system such as architecture, landscape, building interiors etc. wherein much of the costs are associated with labour spent on system/equipment maintenance throughout its life cycle.

LCC analysis provides better insights on all costs associated with the entire life span of the system/equipment, including operations and maintenance cost, manpower savings, replacement cost etc. As such, LCC analysis provides a clear differentiation on project alternatives having different useful lives.

3. LCC input

The LCC study in the Maintainability Section (NRB) includes the following inputs:



Note:

** Labour cost must be included as part of the operation and maintenance cost in the LCC study.*

^ Maintenance-related equipment cost refers to use of equipment to facilitate maintenance. For example, the rental cost for scaffoldings for cooling tower maintenance.

 # Replacement cost in the Maintainability Section (NRB) only occurs when baseline and alternative solutions have different life spans.

@ End of life cost varies from building to building and is difficult to estimate with reasonable accuracy without site context. Therefore, it is not included in the Maintainability Section (NRB) LCC study. However, design team is recommended to assess the end of life cost on project to project basis as it might be a significant part of cost for certain building.

4. Study period

The study period for an LCC is the time over which the costs and benefits related to a capital investment decision is calculated. In the Maintainability Section (NRB), the study period is set to the lifespan of the presented solutions with the longest expected lifespan not exceeding 30 years.

<u>Setting the length of study period</u>

In the Maintainability Section (NRB), the study period is guided by the following two assumptions*:

- The study period is the same as the life span of the system/equipment's for either the baseline or alternative solutions, whichever is longer. For example: cooling tower's service life is about 15 years. The study period for cooling tower-related LCC is set at 15 years for both baseline and alternative solution.
- If the life span of certain system/equipment is more than 30 years, then the study period is capped at 30 years. For example, a building façade's life span can more than 30 years. In carrying out the LCC study for building façade access system in the Maintainability Section (NRB), the study period is limited to maximum of 30 years.

**Note: Study period can also be defined by owner's time horizon, i.e. the interested study period by the building owner. Project team shall evaluate and choose the most appropriate study period to suit their purpose.*

5. Labour rate

As mentioned in the earlier section, labour savings represents a crucial outcome of the LCC study in the Maintainability Section (NRB). The labour rate is referenced from NTUC's published rate in 2019[1] and standard schedule of rates (SOR) observed during the data collection.

Table 1. NTUC published labour rates

Type of worker	Wage/hr	Monthly Wage
General indoor cleaner	$6.9	1,200
General outdoor cleaner	$8.1	1,400
Multi-skilled cleaners/machine operators	$9.2	1,600

Table 2. SOR for specialised (e.g. M&E) works*

Type of worker	Rates
Semi-skilled worker	$20/ hr/ ppl
Skilled worker	$40/ hr/ ppl
Specialist	$80/ hr/ ppl

**The SOR is based on local data collected in 2019 when the Maintainability Section (NRB) LCC exercise was conducted and is only for reference. Project team shall use the project specific SOR for LCC study.*

6. LCC output

Man-hour Savings

Total Life Cycle cost

Savings to Investment Ratio (SIR)

Adjusted Internal Rate of Return (IRR)

Payback Period

[1] https://ntuc.org.sg/wps/wcm/connect/b30e4bd7-aea9-4c4b-9ed9-5b6202a70d67/Tripartite+Cluster+for+Cleaners+Report_Dec+2016.pdf?MOD=AJPERES

- Man-hour Saving is the man-hour saving per year for the proposed solution as compared to baseline. Although, man-hour savings is not a direct output from LCC analysis, rather it is instrumental to reduce the operations and maintenance cost which is included in the LCC analysis. The man-hour savings is indicated separately in the Technical guide to better illustrate the productivity gains by adopting the better practice solution.

- Total life cycle cost is the future Net Saving (NS) amount, in present value, it is what the project alternative is expected to save over the study period. An investment is cost effective if the NS is positive.

- SIR is a measure of economic performance for a project alternative that expresses the relationship between its savings and its increased investment cost (in present value terms) as a ratio. An investment is cost effective if SIR is greater than 1.0.

- AIRR is a measure of annual percentage yield from a project investment over the study period. AIRR is compared against the investor's minimum rate of return which is generally equal to discount rate uses in the LCC study.

- Payback Period is the time required to recover incremental (premium) investment cost.

Table 3. LCC Analysis methodology and data input

	Approach
Evaluation Method	Life-cycle cost analysis
Discounting Approach	Present Value (PV) at the base date
Cost Measurement Basis	Constant dollars as of the base date
Cash-Flow Convention	End-of-year cash flows
Evaluation Criteria	Lowest life-cycle cost Highest net saving SIR > 1 AIRR > discount rate
Data and Parameters	
Base Date (year)*	Beginning of study period
Service Date (year)*	Beginning of service period of the system/equipment
Study Period	System life span and maximum to 30-year service period
Discount Rate**	3%

Rate of Increase (Labour and material) **	0.1%

**For the Maintainability Section (NRB) LCC, base date/year is set as 2019. The first cost is accounted in 2019. It is assumed that the service date/year starts from next year, i.e. 2020. O&M cost is accounted at the end of one-year operation.*

***The discount rate and rate of increase in labour and material is based on local (Singapore) data in 2019.*
Key assumptions in adopting the discount rate and rate of Increase (Labour and material):

a. *Considering the guaranteed interest rates offered by local bonds offerings and banks, which is the range of 0.17% to 1.13% (from 2010 to 2019) and ISO15686-5, 2017 which suggests a discount rate between 0-4%, a discount rate of 3% is adopted for the Maintainability Section (NRB) LCC study.*

b. *The "Rate of Increase" in LCC study is the combined rate of increase for inflation rate (building maintenance related materials/equipment replacement), escalation rate of FM-related labour cost and electricity cost. Locally, we note a downward trend in the electricality prices and SOR rates for materials/ equipment replacement have remained largely unchanged over the past 10 years (2010-2019). To represent a long-term trend of rate of increase, a conservative value of 0.1% is used for LCC study.*

7. Notional building

The Maintainability Section (NRB) adopts a notional building to compare the initial capital cost and O&M cost of baseline and best practice solutions for the LCC study. The notional building is taken as a typical class-A office building (see Figure 1 & 2 and Table 4 for more information).

Figure 1. Notional building perspective

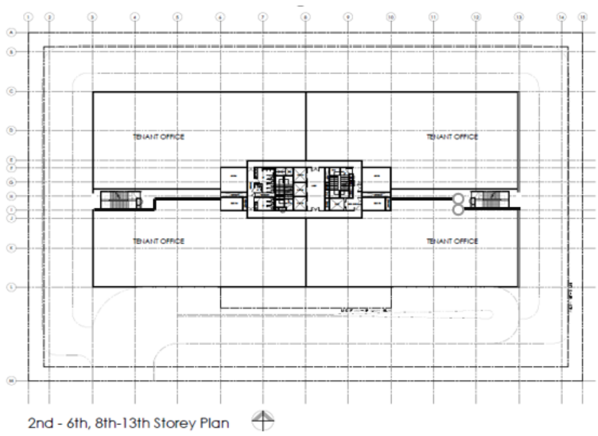


Figure 2. Typical floor plan

Table 4. Notional building information

S/N	Key Design Criteria	Description
1	Site Area	8,246 sqm
2	No. of Floors	14 +2basements
3	Total GFA	49,824 sqm
4	Floor Plate (Typical)	3,466 sqm

5	Air-Conditioning Area	42,990 sqm
6	Construction Cost	\$3,500/m^2 GFA (\$2,800/m^2 CFA) *

** https://www.arcadis.com/en/knowledge-hub/perspectives/asia/research-and-publications/quarterly-construction-cost*

8. Tool Used for the Maintainability Section (NRB) LCC Study

The NIST "Building Life Cycle Cost" (BLCC) software tool is adopted in the Maintainability Section (NRB) to perform LCC analysis of building systems or solutions. More details on the BLCC software, assumptions and methodology can be accessed here: *https://www.energy.gov/eere/femp/building-life-cycle-cost-programs*

9. LCC Example

This segment provides an example of the LCC analysis for one the Key Maintenance Issue (KMI) stipulated in the Maintainability Section (NRB). The objective of this example is to illustrate the key inputs and outputs associated with the LCC study. On the data inputs, this LCC example captures the key assumptions including number of equipment, operating schedule, first cost, and operations & maintenance cost. In terms of LCC output, the LCC study demonstrate some of the key outputs which are necessary for stakeholders to make informed decision; such as total life cycle cost, labour savings, and simple payback.

- Baseline solution: Belt Driven DIDW (Double inlet Double width) centrifugal fan used in typical AHU's. The number of AHUs is derived based on the assumed cooling required in the notional building.
- Proposed solution: Direct drive fan system (i.e. EC fans, plug fans, Axial flow fans etc.). The direct drive fans are considered efficient both in terms of energy efficiency and long-term maintainability. The LCC study captures both the energy savings and man-hour savings associated with direct drive fan system.
- Maintenance issues due to belt driven fans: Frequent alignment/ failure of fan parts i.e. pulley, bearing and belts resulting in downtime and frequent replacement of fan components.
- Intent: Use of a fan system with less moving parts (e.g. fans with direct drive motors) for enhanced reliability and reduced downtime
- Study period: 15 years (the usual life span of fan system)

A detailed breakdown of the assumptions, initial cost, operating and maintenance cost (both tangible and intangible) are be found in Table 5 below.

Table 5: LCC Inputs

AHU Fans	Baseline: AHU/FCU fans with **Belt Driven**	Best Practice: AHU/FCU fans with **Direct Driven** (i.e., EC, axial flow, plug fans)
Assumptions	Notional building: 49 nos of AHU with Belt Driven *(cooling capacity 25RT, motor input power 6.25 Kw)* Operating hours: 55 hours /week x 52 weeks **Belt alignment** should be check **monthly** **Belt tension** should be adjusted **quarterly** **Belt must be replaced** periodically (Approx. **every 3 years** with VSD)	Notional Building: 49 nos of AHU with Direct Driven EC fans *(cooling capacity 25RT, motor input power 4 kW)* Operating hours: same as baseline **No alignment** required Low maintenance, require very little **relubrication every 5 years**
First Cost	$20k per fans * 49 nos of fans = $980k	$28k per fan * 49 nos of fans = $1.372mil
Operation & Maintenance Cost	**Utility Cost** AHU energy consumption = 6.25 x49 x 55 x 52 = 875,875 MWh Electricity cost =875,875 * $0.2/kWh = $175.175k **Belt Alignment (monthly)** 2 skilled technicians ($80/hr) x 1/6 hrs (~10 mins/AHU) x 49 nos x 12 times/ year Yearly cost = $15,680 Total manhours: 196 **Belt Tension (quarterly)** 2 skilled technicians ($80/hr) x 24 hrs (~30 mins/ AHU) x 4 times a year Yearly cost = $15,680 Total manhours: 196 **Belt Replacement (every 3 years)** Equipment Cost for three years: $150 each belt x 49 no's = 7,350 Labour Cost for 3 years: 2 skilled workers x 2hr per belt x 49 no's = 2 x 2 x $80 x 49 =$15,680 Annualized belt replacement cost=($7,350+$15,680)/3= $7,677 Annualized manhours : 196/3=65 **Total maintenance cost /year: $214,212** **Total man-hours spent/year: 457**	**Utility Cost** AHU energy consumption = 4 x49 x 55 x 52 = 560.56 MWH Electricity cost =560.56 * $0.2/kWh = $112.112k **Relubrication** (Every 5 years) 2 skilled technicians ($80/hr) x 1/6 hrs (~10 minutes/AHU) x 49 nos/ 5 years =$261.3 **Total maintenance cost/year: $112,373** **Total man-hours spent/year: 4**
Saving on Man-hour/year	-N/A	453
Environmental Friendliness	-	Quiet operation, lower noise level throughout the entire fan performance Less CO_2 emission with high efficiency motor
Safety	-	Reduced hazard associated with handling the fan during its operational periods All control components and protection electronics are integrated with the motor, easy connection

Table 6: Summary of cost/savings

Input	Baseline Solutions (Belt Driven)	Proposed Solution (Direct Drive Fans)
Initial Cost	$980,000	$1,372,000
Operation & Maintenance /Year	$214,212	$112,373
Man-hour/ Year (Man-days/ year)	457 (57.1)	4 (0.5)

Table 7 LCC output example

	Baseline solution AHU/Fans with belt driven	Best Practice Solution AHU/FCU fans with direct drive motors	Savings from Proposed Solution
Initial Investment Cost (S$)	980,000	1,372,000	-392,000
Annual O&M Cost (S$)	214,212	112,373	101,839
O&M Cost – Present Value (S$)	2,369,351	1,242,419	1,126,932
Total Life Cycle Cost (Present Value) (S$)	3,349,351	2,614,419	734,932
Labour Saving (Man hour/year)	453		
Simple Payback Period (year)	3.84		

Figure 3: 40% higher on initial investment

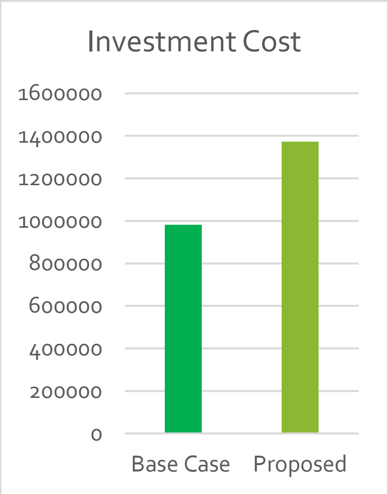


Figure 4: 47% reduction on annual O&M cost

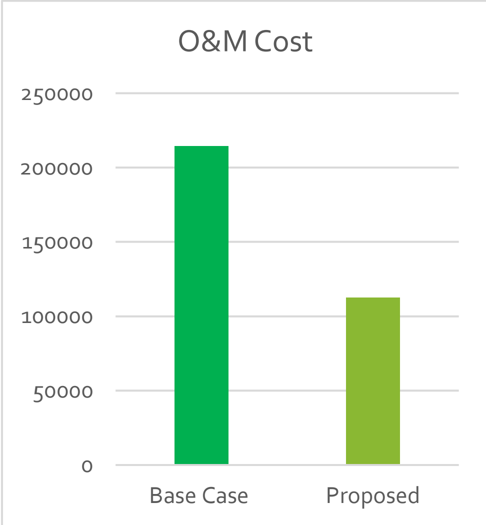


Figure 5: 21% reduction on total life cycle cost

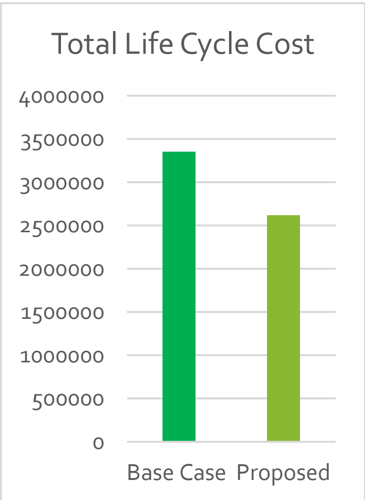
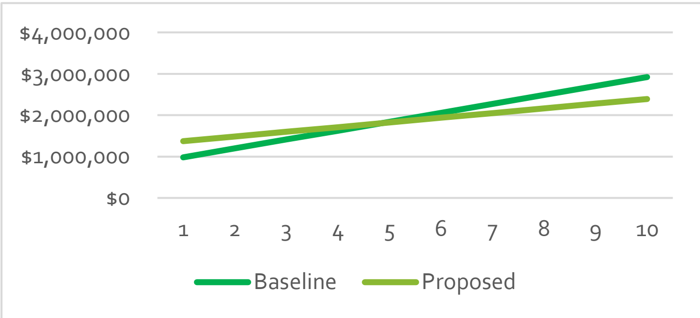


Figure 6: Payback period



10. Maintainability premium

- While the term "Maintainability Premium" is used – drawing semblance to Green Premium – the actual consideration here is an adjustment in first cost for under-investment in maintainability, rather than a premium of sort. The idea here is that Maintainability is part of sensible design to ensure downstream maintainability regimes remain resource-efficient over the life span of a building. Hence, any increase in first cost to enhance maintainability is a must-have investment rather than seen as premium. Notwithstanding, for convenience, we are using the term "premium".

- The Maintainability Section (NRB) comprises about 120 better practice solutions. While the intent is to undertake LCC analysis on all solutions, this is however not feasible for the following reasons:

- For the purposes of LCC computations, solutions need to comprise quantitative elements
- Spatial-related solutions for ease of maintenance are considered as a basic design responsibility and not included in the LCC analysis, e.g. access within the chiller plant and AHU rooms
- Few design and detailing related solutions such as plant room ventilation, slope for condensate drain, roof slope, and waterproofing for retaining walls are deemed essential enough to be addressed in the base design and excluded in the LCC analysis

- Notwithstanding the above, LCC analysis was undertaken on access provisions which reduces significant man-hours and incur considerable efforts to implement the solution, e.g. cooling tower maintenance platform and façade access system. Overall, the LCC study was carried out on 26 architecturally-related LCCs and 11 M&E-related LCC studies.

- Since the LCC studies are based on the notional building, it is important that project parties undertake project-specific LCC studies to accurately capture the adjustment in the first cost for their respective projects.

- In deriving the maintainability premium, it is important to exclude the cost associated with solutions included in the Green premium, to avoid double accounting of the capital cost and overall Life cycle cost. The focus of maintainability premium is different from that of the green premium typically considered for Green Mark cost benefit analysis. While the Green premium focuses into utility cost savings, the maintainability premium focuses on cost and labour saving arising from improved productivity and ease of maintenance. However, some solutions may include both man-hour savings and utility cost savings due to better maintainability provisions, e.g. cooling tower water treatment which has both maintainability benefits and utility cost savings due to better heat transfer in the chiller system. Same goes for auto-tube cleaning system and few other solutions listed in this Maintainability Section (NRB).

- The LCC study for the Maintainability Section (NRB) was aimed at understanding the maintainability premium for obtaining the Maintainability Badge *(i.e. attaining at least 10 out of the available 15 points under the Maintainability Section)* for a non-residential development, using the notional building. The approach was to aggregate the costs associated in adopting the better practice solutions. The range of solutions adopted was based on a balance of cost, design strategy, and impact for a project aiming for the Maintainability badge. The payback was estimated to take up to 5 years, with an aggregated potential annual labour savings of up to 1,100 man-days/year.

CRITERIA			Points
Section 0 – GENERAL			
0.1	General Project Requirement		7
	Sub-total score for Section 0		7
Section 1 – ARCHITECTURAL EXTERIOR			
1.1	General Façade	Part A	0.5
	Part A: Subtotal of 1.1		0.5
1.2	Cladding system: Tile/Stone/Metal/Others	Part B: Façade System	4
1.3	Curtain Wall		4
1.4	Masonry and Lightweight Concrete Panels		4
	Part B: Subtotal of 1.2 to 1.4, including pro-ration)		4 (Max)
1.5	Façade Features / other façade considerations		3
1.6	Entrance lobby		3
1.7	Roof		-
	Part C: Subtotal of 1.6 to 1.7		6
	Sub-total score for Section 1(Part A + Part B+ Part C)		10.5
Section 2 – ARCHITECTURAL INTERIOR			
2.1	Floors		2.5
2.2	Ceilings		4
2.3	Wet Rooms and Storage		8
2.4	Basements		4
2.5	Loading Bay/ Back of House Service Areas		2.5
	Sub-total score for Section 2		21
Section 3- MECHANICAL			
3.1	Chiller Plant	Part A: Cooling Systems	9.5
3.2	Unitary Air Conditioning System – Variable Refrigerant Flow (VRF)		1
	Part A: Subtotal for cooling systems (apportioned 3.1 and 3.2)		9.5 (Max)
3.3	Air Distribution System	Part B	4
3.4	Domestic Water Supply		-

3.5	Sanitary System		2
3.6	Fire Protection System		2
3.7	Building Management System		1
	Part B: Subtotal of 3.3 to 3.7		9
	Sub-total score for Section 3 (Part A + Part B)		18.5
Section 4- ELECTRICAL			
4.1	Lighting System		2
4.2	Power Distribution System		2
4.3	Extra Low Voltage (ELV) System		3
4.4	Lightning Protection System		1
4.5	Vertical Transportation System		2
4.6	Solar PV System		0.5
	Sub-total score for Section 4		10.5
Section 5 - LANDSCAPE			
5.1	Softscape		1.5
5.2	Hardscape		4
5.3	Vertical Greenery		-
5.4	Roof, Sky Terraces, and Planter Boxes on building edge/facade		1.5
5.5	Water Retaining Structure		2
5.6	Standalone Structures		1.5
	Sub-total score for Section 5		10.5
Section 6 – SMART FM			
6.1	Good practices		2
6.2	Cybersecurity		1
6.3	Innovation		3
6.4	Advanced Smart FM		4
6.5	Robotics & Automation		3
	Sub-total score for Section 6		13
		Overall Maintainability Points	***91***

SECTION 0 – GENERAL

0. GENERAL REQUIREMENTS (UP TO TOTAL 7 POINTS)

Promote inclusion of Design for Maintainability (DfM) at planning and design stage

Intent

To maximise opportunities for integrated, cost-effective adoption of good design and construction strategies. Emphasising maintainability as a fundamental evaluative criterion for building design, construction, and operations.

Design Strategy and assessment: (prerequisite & 1 point)

a. Promote integrated design approach and stakeholder engagement at planning and key design stages.

i) Conduct at least 3 design charrettes during the concept/ detail design stage involving minimally 3 stakeholders from the following group (prerequisite):

- **Building owner/ representative**
- **Facilities manager (FM)/operator**
- **Design consultants (minimally one representative each from the various disciplines – architecture, civil & structural, mechanical, and electrical, landscape, quantity surveyor, etc.)**
- **Other specialist consultant / supplier (i.e. environmentally sustainable design, lighting specialist, material specialists, façade access consultant, etc.)**

As early as practicable during the design stage, conduct at least 3 design charrettes to optimise integration of design for maintainability upstream, drawing inputs from stakeholders across the value chain.

The design charrette should accomplish the following:

- To draw design team members' attention on design for maintainability
- To share the background of design for maintainability framework
- To identify potential downstream maintenance issues due to the proposed design/ nature of project
- To identify the desired certification level and points targeted
- To generate potential solutions and maintenance strategies that improve the maintenance regimes

ii) Use of 5-step SMART process to evaluate building's potential to implement Smart FM, and to identify suitable solutions that will streamline FM maintenance process, improve productivity and service delivery. (prerequisite)

The 5-step SMART FM process is described in "Guide to Smart FM" which available on BCA's website.

The project team (including developer and facilities manager) must collaborate closely on this write up. To facilitate the process, the project team may refer to the guiding questions below.

5 Step Smart Process	Guiding Questions
Step 1 – Set business objectives and outcomes	• What do I want to achieve and set as my FM outcomes? • What KPIs can I set to monitor these outcomes? • How will these KPIs be tracked? • What FM services should I prioritize to meet these outcomes?
Step 2 – Map out Smart FM solutions as enablers	• What are the smart fm solutions that can help me achieve the outcomes? • What level of "smartness"? Type 1, 2 or 3? • How are these multiple smart fm solutions integrated? • Is there a system architecture diagram that explains how data would flow across the smart fm solutions?
Step 3 – Adopt suitable implementation model	• What solutions will be owned the building owner? • What solutions will be owned by the FM company or service provider? • Will the building owner own all the data regardless of the implementation model?
Step 4 – Review procurement contract	• What is the contract period? • Can outcome-based contracts be adopted with these smart fm solutions? • Can Integrated FM contracts be adopted with these smart fm solutions?
Step 5 – Track outcomes and review for continuous improvement	• How will these KPIs be tracked? • When will the KPIs be reviewed?

iii) Design for maintainability report, as part of the O&M manual, outlining the key maintainability considerations and provisions. (1 Point)

The DfM report should be led by the design consultants with inputs from the contractor. It must be handed over to the eventual owner/user who will maintain the development.

It should state the designers' proposed maintenance considerations and strategies which typically include, but not limited to the following:

- unique requirements of the project
- areas requiring maintenance access (including spatial and structural requirements, etc.)
- anticipated maintenance tasks and frequency
- materials / equipment that have specific maintenance requirements

proposed/ assumed maintenance methodology (equipment, methods, etc.)

Documentation requirements

Design Stage

- Stakeholders involved in the discussion on Design for maintainability .
- Documents demonstrating the integrative design process via correspondences, meeting agenda, minutes of meeting etc. recorded during the design charrettes.
- 5-step smart FM process report signed by developer

Verification Stage

- Design for maintainability report
- Submit as-built drawings, photographs, and/or O&M manuals highlighting the maintainability features installed on site.
- Updated 5-step smart FM process report signed by developer and facilities manager

Design strategy and assessment: (up to 2 points)

b. Use of life cycle cost (LCC) approach[2,3] to identify solutions with better economic and maintainability benefit throughout the building life span.

i) Undertake project-specific LCC analysis on adopted solutions with LCC filter, listed in this appraisal system for. (0.5 points per LCC, up to 2 points)

Documentation requirements

Design Stage

- Life cycle cost analysis report for selected items (pls refer to the LCC chapter).

Verification Stage

- NA

Design strategy and assessment: (Up to 4 points)

c. Maintenance contract

Use of outcome-based contracts and integrated facilities management (IFM) contracts to improve labour efficiency.

i) Projects demonstrating outcome-based maintenance contract for the following services:
(1 point for each item, up to 2 points)

- **Chiller plant**
- **Air distribution**
- **Cleaning (toilets, waste management, etc.)**
- **Landscape**
- **Security**

[2] NIST Handbook 135, Life-cycle Costing Manual for the Federal Energy Management Program
[3] ISO 15686-5, Building and Constructed Assets – Service Life Planning, Part 5: Life-cycle costing, 2nd edition. 2017

ii) Projects demonstrating integrated facilities management (IFM) contracts for the following maintenance services:
(1 point for 2 maintenance services, up to 2 points)

- **Building maintenance services**
- **Mechanical and Electrical maintenance services**
- **Security services**
- **Cleaning services**
- **Landscape services**
- **Pest control services**

Outcome-based service does not prescribe the required headcount/ frequency of maintenance to deliver quality services. Instead it specifies the desired service outcome. It enables service providers to adopt innovative technology, enhance processes, and offer better solutions to improve productivity and deliver quality service. An early decision on performance-based service during design stage enables designers to make necessary design provision/ detailing to allow outcome-based contracting during building operations.

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
100% (No provision for baseline)	5%-10%	Up to 5%	5-6

Baseline design strategy: No performance contract
Proposed design strategy: Chiller plant with performance contract
Study period: 15 years
Yearly labour saving: 15%-20% Man-hour

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
100% (No provision for baseline)	5%-10%	Up to 5%	3-4

Baseline design strategy: No performance contract
Proposed design strategy: Chiller plant + AHU with performance contract
Study period: 15 years
Yearly labour saving: 15%-20% Man-hour

Documentation requirements

Design Stage

- Meeting notes from the design charrette highlighting the systems shortlisted for outcome-based contracting and the design provisions.
- Tender Specification showing the requirement on outcome-based maintenance contract and integrated FM contract.
  OR
- Contract clauses highlighting the outcome-based maintenance and integrated FM contract.

Verification Stage

- Outcome-based and integrated FM contracts.

SECTION 1 – ARCHITECTURAL EXTERIOR

Part A: SECTION 1.1

1.1. GENERAL FAÇADE (0.5 points)

1.1.1 Reduce risk of water ingress and streaking on façade (0.5 points)

Intent

External façade cladding of various materials (e.g. metal, glazing, stone or tile, and masonry wall) and façade features e.g. canopies, sunshade, niches, fins, ledges, photovoltaic panels, BIPV etc. requires regular cleaning maintenance or repair at façade joints to ensure water tightness. Frequency of cleaning or repair on façades and risk of water ingress and streaking can be reduced with optimal façade design and detailing.

Design strategy and assessment: (prerequisite)

a. **Design for drip edges/grooves to mitigate streaking on exterior soffits and vertical façade surfaces e.g. leading edge of flashing, sills, overhangs, or other horizontal projecting façade elements.**

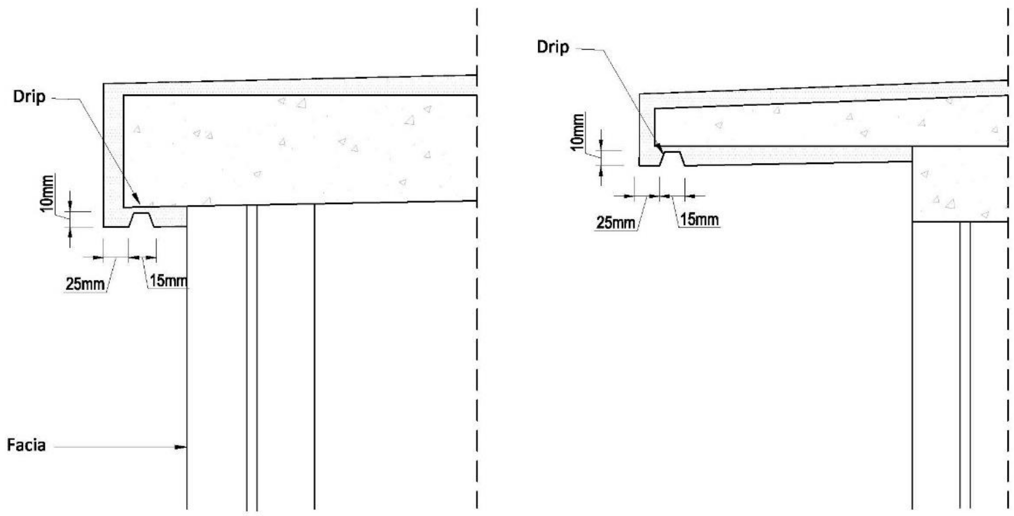


Figure 7: Typical drip edge detail on projected façade elements. Image on the left illustrates detail on recessed window and image on right illustrates detail on sunshades.

Documentation requirements

Design stage

- Plan/elevation drawings locating drip edge detail on the façade surfaces.
- Detail drawings showing façade drip edge detail.

Verification stage

- As-built drawings/shop drawings of façade indicating drip edge detail.
- Photographs of incorporated drip edge detail after implementation.

Design strategy and assessment: (0.5 point)

b. Design all top surface of walls to slope away from the external face of façade

Note: Top surface of wall or coping must have overhang on the rear side with drip control to mitigate streaks on the back walls (OR) equivalent measures.

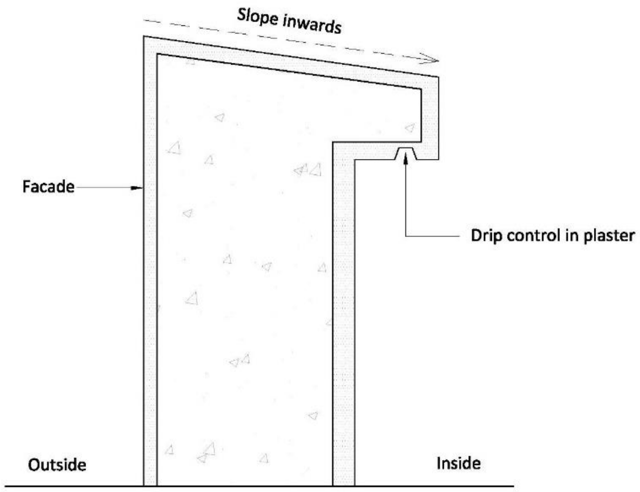


Figure 8: Drawing illustrating slope gradient on top surface of external wall.

Documentation requirements

Design stage

- Plan drawings locating all relevant top surface of wall that slope away from exterior face of façade.
- Detail section drawings showing slope.

Verification stage

- As-built drawings/shop drawings showing slope incorporated on top of wall surfaces.
- Photographs of incorporated slope after implementation.

1.1.2 Access for maintenance of façade (prerequisite)

Intent

To ensure safe and efficient access to facilitate cleaning, repair & replacement, and inspection of façade.

Design strategy and assessment: (prerequisite)

a. Ensure entire façade is accessible for maintenance.

Note:

- *Façade: including wall, cladding (stone, tile, metal, and glazing), openings, structural members, railings, façade features (sun-shading devices), and M&E systems (façade lighting, media walls, solar panels [BIPV])*
- *Sole use of rope access is deemed unacceptable since maintenance comprises regular cleaning, minor repair & replacement, and inspection; all of which cannot be undertaken by rope access.*
- *Access for façade maintenance, if accessible from within the building, must not be via tenanted/leased out spaces.*

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
6.8X- 6.9X	75% - 80%	30% - 35%	11 - 12

Baseline design strategy: Davit arm (gondola) for cleaning and glass replacement
Proposed design strategy: Automated BMU for cleaning and glass replacement
Study period: 30 years
Yearly labour savings: 100-150% man-hour

Documentation requirements

Design stage

- Plan/elevation/schematic drawings indicating entire façade is 100 % accessible through one or a combination of façade access systems. Please refer to BCA's façade access design guide[4] for more details on the submittals.

Verification stage

- Maintenance strategy report for façade access.

1.1.3 Access for maintenance to façade, soffit, and roof of sky bridges (prerequisite)

Intent

To ensure safe and efficient access to facilitate cleaning, maintenance, and of façade and roof of sky bridges.

Design strategy and assessment: (prerequisite)

a. Ensure the roof, façade and soffit of skybridge are accessible for maintenance.

Note: Sole use of rope access is deemed unacceptable unless proven otherwise.

Documentation requirements

Design stage

- Plan/elevation/schematic drawings demonstrating entire roof and façade of skybridge is 100 % accessible through one or a combination of access systems. Please refer to BCA's façade access design guide[5] for more details on the submittals.

Verification stage

- Maintenance strategy report for skybridge's roof and façade access.

[4] Refer to BCA Façade Access Design Guide to provide required details on Façade access strategy, façade features etc. https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/dm_fadg_2017.pdf

[5] Refer to BCA Façade Access Design Guide to provide required details on Façade access strategy, façade features etc. https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/dm_fadg_2017.pdf

(For singular façade system, *points are scored for 1.2, 1.3 or 1.4. In case project comprises multiple façade systems, points will be apportioned on an area basis)*

1.2. CLADDING – TILE / STONE / METAL / OTHERS (4 points)

1.2.1. Reduce risk of water ingress and streaking on façade (up to 4 points)

Intent

To ensure water tightness and minimise façade streaking through optimal design detailing and choice of materials to reduce the frequency of repair and maintenance.

Design strategy and assessment: (prerequisite)

a. **For streaking:**
   Specify metals of similar properties or separators between different metal components on the exposed face of the façade to mitigate risk of bi-metallic corrosion.

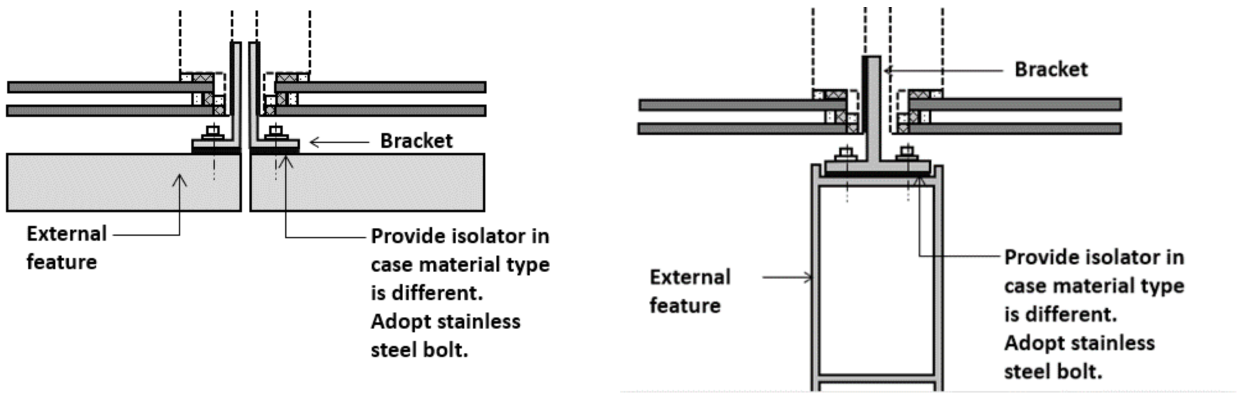


Figure 9: Example – plan drawing (detail) on left and right illustration connection between curtain wall and metal external feature on the exposed face of the facade. Providing metals of similar properties or separator/isolator helps to mitigate risk of bi-metallic corrosion.

Credits: YKK AP FAÇADE

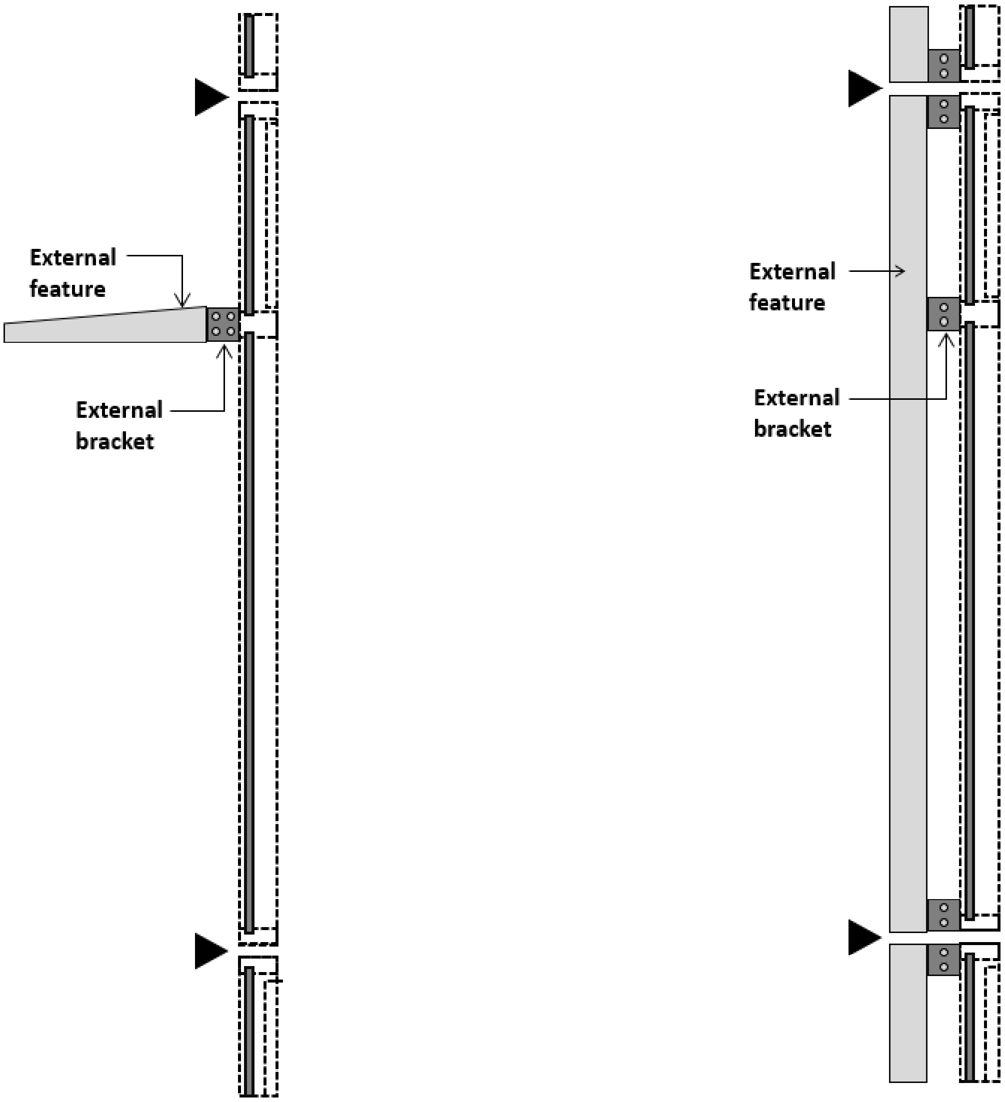


Figure 10: Example - section drawing (detail) on left and right illustrating connection between curtain wall and metal external feature on the exposed face of the facade. Providing metals of similar metal properties or separator/isolator helps to mitigate risk of bi-metallic corrosion.

Credits: YKK AP FAÇADE

Documentation requirements

Design stage

- Tender specification indicating metals of similar properties or separators between different metal components on the exposed face of the façade.
- Plan /elevation/section and detail drawings indicating metals of similar properties or separators between different metal components.

Verification stage

- As-built (façade shop drawings) to show implementation.
- Product specification indicating the properties of the metal components.

b. For water ingress – design for a pressure-equalised (rain-screen) system, comprising:

i) **Ventilation openings of adequate dimensions to ensure pressure-equalisation of the cladding cavity.**

ii) **Drainage system to positively drain out water.**

iii) **Air cavity with a fully sealed internal backing wall behind the cladding.**

Note:

- *Pressure Equalised System (PES) act like a typical cavity wall to allow rainwater discharge and moisture ventilation (like breathable façades) to reduce risk of water ingress through external walls. Water ingress is reduced by 'equalisation' of internal and external pressures (pressure moderated system).*
- *The table below shows the solution permutation feasibility under section 1.2 for PES and Non - PES façade systems.*

Solutions under 1.2	PES system	Non - PES system
1.2.1a	yes	yes
1.2.1b	yes	No
1.2.1c	NA	yes
1.2.1d	NA	yes
1.2.1e	yes	NA
1.2.1f	yes	yes
Advanced effort	yes	yes

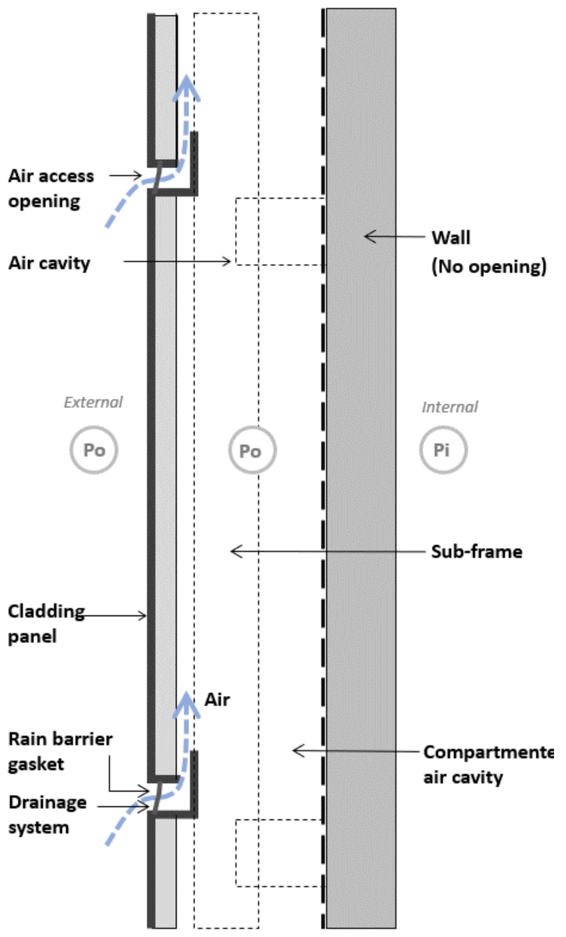


Figure 11: Drawing illustrating pressure equalised metal cladding system.

Credits: YKK AP FAÇADE

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
20% - 25%	70% - 75%	Up to 5%	20 – 25

Baseline design strategy: Non pressure equalised system
Proposed design strategy: Pressure equalised system
Study period: 30 years
Yearly labour savings: 60-70% man-hour.

Documentation requirements

Design stage

- Plan/elevation drawings indicating open joint, pressure equalised stone/tile cladding system and extent, in case of different cladding system.
- Detail drawings of open joint, pressure equalised stone/tile cladding system.

Verification stage

- As-built (façade shop drawings) to show implementation.

Design strategy and assessment: (1 point)

c. For water ingress - In face-sealed cladding: specify silicone or modified silicone sealant that is compatible and with adequate adhesion properties to the substrate.

Note:

- *Silicone: 100% Silicone is an inorganic substance with outstanding UV resistance and thermal stability.*
- *Modified Silicone (MS): is an organic substance which is hybrid between Silicone and Urethane. Silicon in its chemical formulation, provides the properties that 100% Silicone has and is paintable because of the Urethane polymer in it.*
- *Proposed silicone or modified silicone for stone/tile cladding has to be tested to Adhesion-in-Peel in compliance to ASTM C794[1]6. The test should include but not limited to various primer solutions and testing without primer.*
- *Proposed silicone or modified silicone is recommended to have minimum properties of +50% movement capability, tested in compliance with ASTM C920[2][7] for Class 50.*
- *External application must be conducted in dry weather condition as sealant does not adhere well on wet, damp or frozen surface. Ensure the joint is dry, clean and free from contaminants.*

Documentation requirements

Design stage

- Plan/elevation drawings indicating all tile and stone façades using sealants.
- Tender specification using sealant type as silicone or modified silicone.

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[6] ASTM C794-18, Standard Test Method for Adhesion-in-Peel of Elastomeric Joint Sealants, ASTM International, West Conshohocken, PA, 2018, www.astm.org
[7] ASTM C920-18, Standard Specification for Elastomeric Joint Sealants, ASTM International, West Conshohocken, PA, 2018, www.astm.org

- Tender specification indicating (i) adhesion and compatibility tests for the specified sealant type and (ii) in the event of failure in adhesion test, use of primer with the specified sealant.

Verification stage

- Test reports showing adhesion and compatibility results.
- Product specification and delivery orders of the sealant used and primer, if any.

Design strategy and assessment: (0.5 point)

d. For streaking – specify sealant type with non-stain, non-bleed properties.

Note:

- *Sealant may cause stain on a porous substrate such as tile or stone. The non-stain and non-bleed properties reduce exudation from the sealant, thus minimising staining.*
- *In Metal cladding - sealant on the facade may cause streaking due to bleeding of oil which grab dust particles. The latter forms streaks during rain. Sealant with non-stain and non-bleed properties to be used to reduce dust deposition and resultant streaking.*

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
Up to 5%	30% - 35%	Up to 5%	4 - 5

Baseline design strategy: Sealant without non-bleed, non-stain properties
Proposed design strategy: Sealant with non-bleed, non-stain properties
Study period: 10 years
Yearly labour savings: 40-50% man-hour

Documentation requirements

Design stage

- Plan/elevation drawings locating all tile and stone façades using sealants.
- Tender specification indicating sealant type with non-stain and non- bleed properties and in compliance with ASTM 1248 standards[8].

Verification stage

- Product specification showing the non-stain and non-bleed property for the sealant type used and delivery orders of the specified sealant.
- Test reports showing compliance of standards.

Design Strategy and assessment: (1 point)

e. For water ingress - specify gasket type EPDM or TPE.

[8] ASTM C1248-06, Standard Test Method for Staining of Porous Substrate by Joint Sealants, ASTM International, West Conshohocken, PA, 2006, www.astm.org

Documentation requirements

Design stage

- Plan/elevation drawings indicating all tile and stone façades using gaskets.
- Tender specification indicating gasket type as EPDM or TPE complying to ASTM C864-05 standards[9].

Verification stage

- Product specification of the gasket type used to show compliance of standards and delivery orders.

Design strategy and assessment: (0.5 point)

f. For water ingress - design for double layer protection at façade interfaces, coping, etc.

Note:

- *A double layer protection reduces risk of water ingress even in case of damaged or peeled primary layer of protection (e.g. Sealant). Façade interfaces, façade copings, and flashing areas that are vulnerable and at risk of failure of 1st layer of protection (e.g. Sealant) can incorporate double layer protection for better protection.*
- *In case of sealant, external application must be conducted in dry weather condition as sealant does not adhere well on wet, damp or frozen surface. Ensure the joint is dry, clean and free from contaminants.*

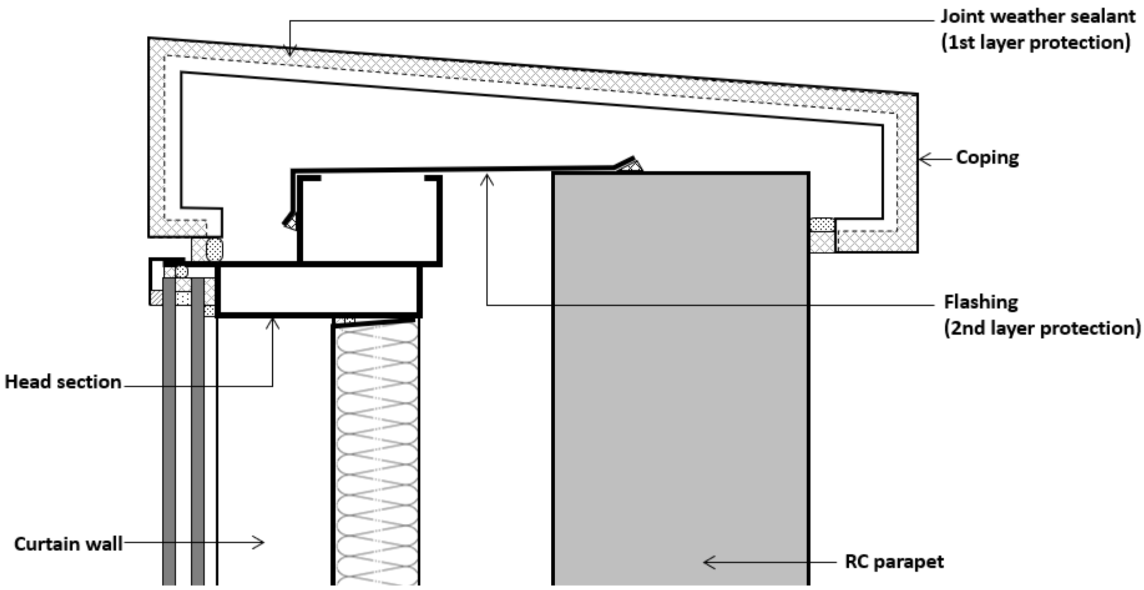


Figure 12: Drawing illustrating double layer protection at façade copping, in this case sealant (1st layer of protection) and flashing (2nd layer of protection).

Credits: YKK AP FAÇADE

[9] Refer to ASTM C864-05(2019), Standard Specification for Dense Elastomeric Compression Seal Gaskets, Setting Blocks, and Spacers, ASTM International, West Conshohocken, PA, 2019, www.astm.org.

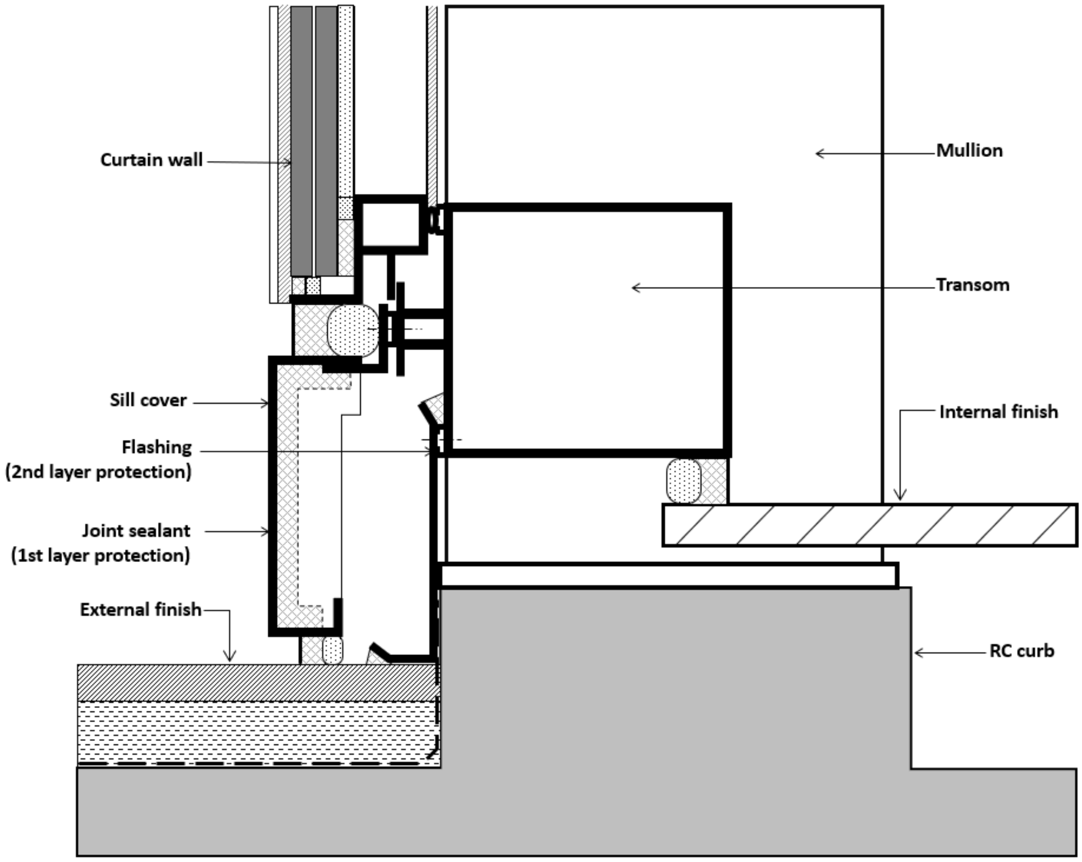


Figure 13: Drawing illustrating double layer protection at bottom flashing, in this case sealant (1st layer of protection) and flashing (2nd layer of protection).

Credits: YKK AP FAÇADE

Documentation requirements

Design stage

- Plan/elevation drawings indicating double layer protection on the façade.
- Typical detail drawings of double layer protection.

Verification stage

- As-built drawings (façade shop drawings) to show implementation.

Advanced effort: (Bonus 1 point)

Advanced effort: For water ingress - Specify anti-carbonation coating or waterproofing later onto the backing wall behind the cladding.

Documentation requirements

Design stage

- Plan drawing locating anti – carbonation coating or waterproofing layer on the backing wall behind the cladding.
- Tender specification indicating anti – carbonation coating or waterproofing layer on the backing wall.

Verification stage

- Delivery orders of product.
- Photographs showing implementation.

1.3 **CURTAIN WALL (4 points)**

1.3.1 Reduce risk of water ingress and streaking on façade (Up to 4 points)

Intent

To ensure water tightness and minimise façade streaking to reduce the frequency of repair and maintenance.

Design strategy and assessment: (prerequisite)

a. For streaking:
Specify metals of similar properties or separators between different metal components on the external face of the façade to mitigate risk of bi-metallic corrosion.

Documentation requirements

Design stage

- Tender specification indicating use of metal components with similar properties or separators between different metal components on the exposed face of the façade.
- Plan/elevation/section and detail drawings indicating metal with similar properties or separators between different metal components.

Verification stage

- As-built (facade shop drawings) to show implementation.
- Product specification indicating the properties of the metal components.

Design strategy and assessment: (2 points)

b. For water ingress – design for pressure-equalised system comprising:

i) Ventilation openings of adequate dimensions to ensure pressure-equalisation of the cavities
ii) Drainage system to positively drain out water
iii) Internal air-seal layer to pressurise internal cavities and minimise risk of water penetration

Note:

- Pressure Equalised System acts like a typical cavity wall to allow rainwater discharge and moisture ventilation (like breathable façades) to reduce risk of water ingress through external walls. Water ingress is reduced by 'equalisation' of internal and external pressures (pressure moderated system).
- *For mixed developments, where the non-residential component does not have a façade system but consist of only full height glass walls for their shopfronts, these glass walls will not be considered for assessment.*
- *The table below shows the solution permutation feasibility under section 1.3 for PES, Non - PES façade systems, and full height glass walls for shopfronts,*

Solutions under 1.3	***PES system***	***Non - PES system***	***Full Height Glass walls for shopfronts***
1.3.1a	*yes*	*yes*	*NA*
1.3.1b	*yes*	*No*	*NA*
1.3.1c	*yes*	*yes*	*NA*
1.3.1d	*yes*	*yes*	*NA*
1.3.1e	*yes*	*NA*	*NA*
1.3.1f	*yes*	*yes*	*NA*

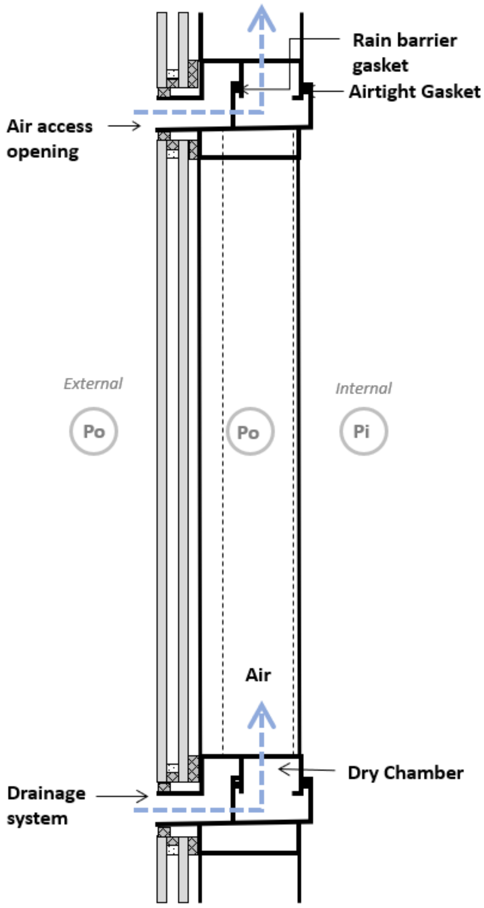


Figure 14: Drawing illustrating pressure equalised system.

Credits: YKK AP FAÇADE

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
20% - 25%	70% - 75%	Up to 5%	20 -25

Baseline design strategy: Non pressure equalised system
Proposed design strategy: Pressure equalised system
Study period: 30 years
Yearly labour savings: 60-70% man-hour.

Documentation requirements

Design stage

- Plan drawings indicating open joint, pressure-equalised glazing system and extent, in case of different cladding system.
- Detail drawings of open joint, pressure-equalised glazing system.

Verification stage

- As-built (façade shop drawings) to show implementation.

Design strategy and assessment: (1 point)

c. **For water ingress - specify silicone sealant that is compatible and with adequate adhesion properties to the substrate.**

Note:

- *Silicon: 100% Silicone is an inorganic substance with outstanding UV resistance and thermal stability.*
- *Proposed silicone for glazing needs to be tested to Adhesion-in-Peel in compliance to ASTM C794[1]10. The test should include but not limited to various primer solutions and testing without primer.*
- *Proposed silicone is recommended to have minimum properties of +50% movement capability, tested in compliance with ASTM C920[2][11] for Class 50.*
- *External application must be conducted in dry weather condition as sealant does not adhere well on wet, damp or frozen surface. Ensure the joint is dry, clean and free from contaminants.*

Documentation requirements

Design stage

- Plan/elevation drawings indicating all glazing façades using sealants.
- Tender specification indicating proposed silicone to be tested to Adhesion-in-Peel in compliance to ASTM C794[1]. The test should include but not limited to various primer solutions and testing without primer

Verification stage

- Test reports showing Adhesion-in-Peel results.
- Product specification and delivery orders of the sealant used and primer, if any.

Design strategy and assessment: (0.5 point)

d. **For streaking - specify sealant type with non-stain, non-bleed properties.**

Note: Sealant may cause stain on a porous substrate such as tile or stone. The non-stain and non-bleed property reduce exudation from the sealant thus minimising the stain.

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
Up to 5%	30% - 35%	Up to 5%	4 - 5

Baseline design strategy: Sealant without non-bleed, non-stain properties
Proposed design strategy: Sealant with non-bleed, non-stain properties
Study period: 10 years
Yearly labour savings: 40-50 % man-hour.

Documentation requirements

Design stage

- Plan/elevation drawings indicating all glazing façades using sealants.

[10] ASTM C794-18, Standard Test Method for Adhesion-in-Peel of Elastomeric Joint Sealants, ASTM International, West Conshohocken, PA, 2018, www.astm.org
[11] ASTM C920-18, Standard Specification for Elastomeric Joint Sealants, ASTM International, West Conshohocken, PA, 2018, www.astm.org

- Tender specification indicating sealant type with non-stain and non- bleed properties and in compliance with ASTM 1248 standards[12]

Verification stage

- Product specification indicating the non-stain and non-bleed property and delivery orders of the specified sealant.
- As-built drawings/shop drawings showing use of specified sealant type.

Design strategy and assessment: (1 point)

e. For water ingress - specify gasket type EPDM or TPE.

Documentation requirements

Design stage

2 Plan/elevation drawings indicating all glazing façades using gaskets.
3 Tender specification indicating gasket type as EPDM or TPE complying with ASTM C864-05(2019)[13]

Verification stage

4 Product specification of the gasket type used to show compliance of standards and delivery orders.

Design strategy and assessment: (0.5 point)

f. For water ingress - design for double layer protection at façade interfaces, coping, etc.

Note:

- *A double layer protection reduces risk of water ingress even in case of damaged or peeled primary layer of protection (e.g. Sealant). Façade interfaces, façade copings, and flashing areas that are vulnerable and at risk of failure of 1st layer of protection (e.g. Sealant) can incorporate double layer protection for better protection.*

- *In case of sealant, external application must be conducted in dry weather condition as sealant does not adhere well on wet, damp or frozen surface. Ensure the joint is dry, clean and free from contaminants.*

[12] ASTM C1248-06, Standard Test Method for Staining of Porous Substrate by Joint Sealants, ASTM International, West Conshohocken, PA, 2006, www.astm.org

[13] Refer to ASTM C864-05(2019), Standard Specification for Dense Elastomeric Compression Seal Gaskets, Setting Blocks, and Spacers, ASTM International, West Conshohocken, PA, 2019, www.astm.org.

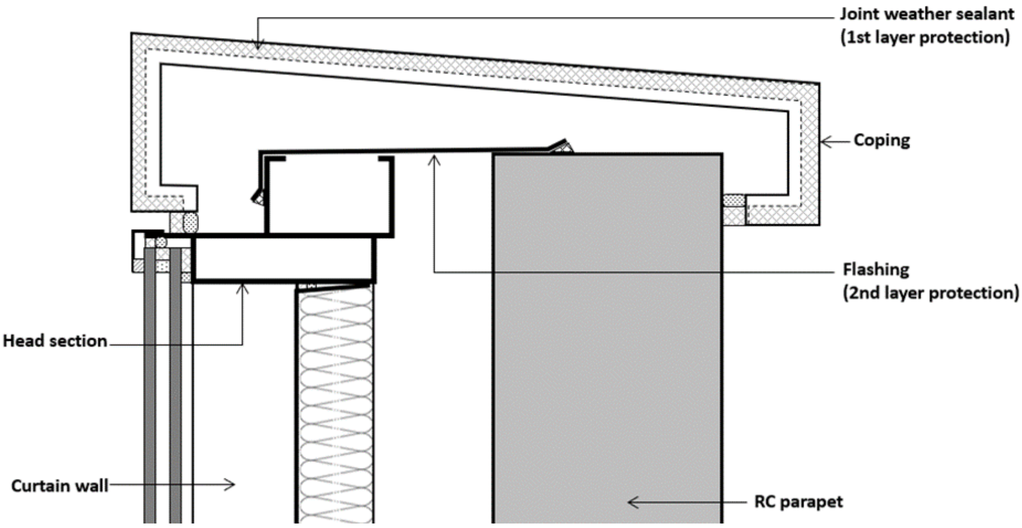


Figure 15: Drawing illustrating double layer protection at façade copping, in this case sealant (1^{st} layer of protection) and flashing (2^{nd} layer of protection).

Credits: YKK AP FAÇADE

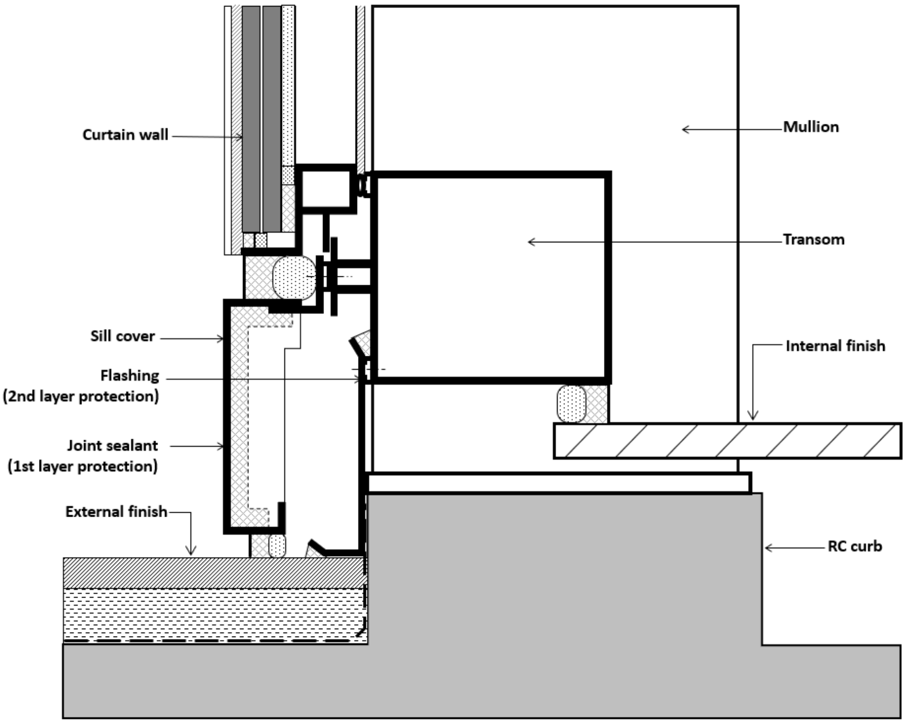


Figure 16: Drawing illustrating double layer protection at bottom flashing, in this case sealant (1^{st} layer of protection) and flashing (2^{nd} layer of protection).

Credits: YKK AP FAÇADE

Documentation requirements

Design stage

- Plan/elevation drawings indicating double layer protection on the façade.
- Typical detail drawings of double layer protection.

Verification stage

- As-built drawings (facade shop drawings) to show implementation.

1.4 MASONRY, LIGHTWEIGHT CONCRETE PANELS, AND PRECAST ELEMENTS (4 points)

1.4.1 Reduce risk of water ingress and efflorescence formation (2 points)

Intent

To ensure water tightness and minimise façade streaking to reduce the frequency of repair and maintenance through optimal design detailing and choice of materials.

Design strategy and assessment: prerequisite

a. **For water ingress: design movement joints in large continuous areas, or between adjacent/different building components, to minimise the risk of damage to façade, weather seal, and waterproofing joints.**

Note:

- *In a continuous surface, movement joints intervals should not be more than 6 m, with minimum width of ½ inch, to accommodate shrinkage after expansion.*

Documentation requirements

Design stage

- Plan drawings indicating all masonry and light weight concrete panel façades.
- Elevation drawings showing movement joints indicating width of movement joints and intervals.

Verification stage

- As-built drawings/shop drawings to show implementation.

Design strategy and assessment: (1 point)

b. **For water ingress in pre-cast components joints – specify silicone or modified silicone sealant on weather-exposed joints, that is compatible and with adequate adhesion properties to the substrate.**

Note:

- Silicon: 100% Silicone is an inorganic substance with outstanding UV resistance and thermal stability.

- Modified Silicone (MS): is an organic substance which is hybrid between Silicone and Urethane. Silicon in its chemical formulation, provides the properties that 100% Silicone has and is paintable because of the Urethane polymer in it.

- Proposed silicone or modified silicone for pre-cast joints must be tested to Adhesion-in-Peel in compliance to ASTM C794[1]. The test should include but not limited to various primer solutions and testing without primer.

- Proposed silicone or modified silicone is recommended to have minimum properties of +50% movement capability, tested in compliance with ASTM C920[2] for Class 50.

- External application must be conducted in dry weather condition as sealant does not adhere well on wet, damp or frozen surface. Ensure the joint is dry, clean and free from contaminants.

Documentation requirements

Design stage

- Plan/elevation drawings indicating all precast facades using sealants.
- Tender specification indicating sealant type as silicon or modified silicon.
- Tender specification indicating proposed silicone or modified silicone for precast to be tested for Adhesion-in-Peel in compliance to ASTM C794[1]. The test should include but not limited to various primer solutions and testing without primer.

Verification stage

- Test reports showing Adhesion-in-Peel results.
- Product specification and delivery orders of the sealant used and primer, if any.

Design strategy and assessment: (1 point)

c. For efflorescence: specify

i. clear coat, with good resistance to water absorption, on façade surface. e.g. fair-faced or pigmented concrete.

(OR)

ii. paint with good resistance to water absorption, complying with SS500 or equivalent

Note: Surface coatings that have good resistance to water absorption reduce the occurrence of efflorescence.

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
Up to 5%	75% - 80%	15 – 20%	1 - 2

Baseline design strategy: standard paint SS345
Proposed design strategy: Paint with good resistance to water absorption, complying to SS500
Study period: 10 years
Yearly labour savings: 60 - 70% man-hour savings

Documentation requirements

Design stage

- Plan drawings indicating façade with coatings / paint with good resistance to water absorption.
- Tender specification indicating clear coat with good resistance to water absorption or paint finish with good resistance to water absorption complying to SS 500 or equivalent.
- Tender specification indicating proposed clear coat or paint finish to be tested for water absorption complying to SS500 requirements or equivalent.

Verification stage

- Test reports showing water absorption results complying to SS 500 or equivalent.
- Product specification and delivery orders of the product.

1.4.2. Reduce risk of façade flaking/peeling/cracking/blistering (Up to 2 points)

Intent

To minimise flaking, peeling, cracking, and blistering due to humidity and dampness through optimal choice of materials so as to reduce the frequency of repainting.

Design strategy and assessment: (2 points)

a. **Specify for integral colours (i.e. directly mixed into the cement) or post-applied stains (impregnator) with inorganic pigments for surfaces which do not require painting.**

Note: Integral colours are admixtures (powder or liquid)/iron oxide pigments infused in concrete, while stains are compounds that when applied react with the chemical present in the concrete to create permanent colours.

Documentation requirements

Design stage

- Plan drawings indicating all surfaces with integral colours in concrete mix or stain on concrete surface.
- Tender specification indicating integral colours in concrete mix or stain on concrete surface.

Verification stage

- As-built drawings (façade shop drawings) to show implementation.
- Product specification and delivery orders of specified products.

Design strategy and assessment: (1 point)

b. **Specify paint finish:**

Top coat:

Paint with good resistance to water absorption complying with SS500 or equivalent.

(OR)

Mineral paint

Note:

- *The appropriate primer coat and undercoat to be recommended by the manufacturer for the specified top coat, taking into consideration the condition of the substrate. The various coats must be compatible.*
- *Proper preparation of surface for paint is mandatory. Ensure that paint selection is suitable for substrate.*

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
Up to 5 %	45% - 50%	25 – 30%	1 - 2

Baseline design strategy: standard paint SS345 with primer (water-based)
Proposed design strategy: Paint with good resistance to water absorption, complying to SS500
Study period: 10 years
Yearly labour savings: 10-20% man-hour savings

Documentation requirements

Design stage

- Plan drawings indicating all external surfaces with paint finish.
- Tender specification indicating use of selected paint finish.
- Tender specification indicating proposed paint finish to be tested for water absorption complying to SS500 requirements or equivalent (if non-mineral paint).

Verification stage

- As-built drawings to show implementation.
- Test reports showing water absorption results complying to SS 500 or equivalent (if non-mineral paint).
- Product specification and delivery orders of applicable products.

Worked Example 1:

A mid-rise office building has been designed with a combination of 3 façade systems – precast concrete panels, a curtain wall system and a metal cladding system. The total area of the façade systems is 5,000m^2. The breakdown is shown in below:

	Metal Cladding (m^2)	Curtain Wall Glazing (m^2)	Lightweight concrete panel (m^2)	Total (m^2)
Facade	900	2100	2000	5000

Area Table I : Breakdown of Façade System

- Proportion of Metal Cladding system
  = 900m^2 / 5,000 m^2 = 18% (≥15%)

- Proportion of Curtain Wall Glazing system
  = 2,100m^2 / 5,000 m^2 = 42% (≥15%)

- Proportion of Lightweight concrete panel
  = 2,000m^2 / 5,000m^2 = 40% (≥15%)

***NOTE:** The maximum points available for Façade Systems - Section 1.2 to 1.4 = 4pts*

(For singular façade system, points can be scored for 1.2, 1.3, or 1.4. In this case as the project comprises multiple façade, systems points will be apportioned across the various systems on an area basis)

1.2 Cladding – Tile / Stone / Metal / Others

***NOTE:** The maximum points available under 1.2 is 18% * 4pts = 0.72pts*

1.2.1 Reduce risk of water ingress and streaking on façade (Up to 4 points)	Points	Assessment category	**Used in Project**	**Points Scored**
a. For streaking: Specify metals of similar properties or separators between different metal	Pre-requisite	NA	√	Complied

components on the exposed face of the façade to mitigate risk of bi-metallic corrosion.				
b. For water ingress: Design for pressure-equalised (rain-screen) system, comprising of: i) Ventilation openings of adequate dimensions to ensure pressure-equalisation of the cladding cavity ii) Drainage system to positively drain out water iii) Air cavity with a fully sealed internal backing wall behind the cladding.	2.5	Cat 1	×	0
c. For water ingress – In face-sealed cladding: specify silicone or modified silicone sealant that is compatible and with adequate adhesion properties to the substrate.	1	Cat 1	√	18% * 1 = 0.18
d. For streaking – specify sealant type with non-staining, non-bleeding properties.	0.5	Cat 1	√	18% * 0.5 = 0.09
e. For water ingress – specify gasket type EPDM or TPE.	1	Cat 1	×	0
f. For water ingress - design for double layer protection at façade interfaces, copings and bottom flashings. 0.5For water ingress - design for double layer protection at façade interfaces, copings and bottom flashings.	0.5	Cat 2	√	18% * 0.5 = 0.09
Score for *1.2 Cladding System*				0.18 + 0.09 + 0.09 = 0.36
BONUS: For water ingress: Specify anti-carbonation coating or waterproofing layer onto the backing wall behind the cladding.	1	Cat 1	√	18% * 1 = 0.18

1.3 Curtain Wall

NOTE: *The maximum points available under 1.3 is 42% * 4pts = 1.68pts*

1.3.1 Reduce risk of water ingress and streaking on façade (Up to 4 points)	Points	Assessment Category	**Used in Project**	**Points Scored**
a. For streaking: Specify metals of similar properties or separators between different metal components on the external face of façade to mitigate risk of bi-metallic corrosion.	Pre-requisite	NA	√	Complied

b. For water ingress – design for pressure-equalised system comprising of: i) Ventilation openings of adequate dimensions to ensure pressure-equalisation of the cavities ii) Drainage system to positively drain out water iii) Internal air-seal layer to pressurise internal cavities and minimise risk of water penetration	2	Cat 1	√	42% * 2 = <u>0.84</u>
c. For water ingress - specify silicone sealant that is compatible and with adequate adhesion properties to the substrate.	1	Cat 1	√	42% * 1 = <u>0.42</u>
d. For streaking – specify sealant type with non-staining, non-bleeding properties.	0.5	Cat 1	√	42% * 0.5 = <u>0.21</u>
e. For water ingress – specify gasket type EPDM or TPE that is compatible with the substrate.	1	Cat 1	√	42% * 1 = <u>0.42</u>
f. For water ingress – design for double layer protection at façade interfaces, copings and bottom flashings.	0.5	Cat 2	×	0
Score for *1.3 Curtain Wall*				0.84 + 0.42 + +0.21 + 0.42 = 1.89 <u>1.68 (max)</u>

1.4 Masonry and Lightweight Concrete Panels

NOTE: *The maximum points available under 1.4 is 40% * 4pts = 1.6pts*

1.4.1 Reduce risk of water ingress and efflorescence formation (2 points)	Points	Assessment Category	**Used in Project**	**Points Scored**
a. For water ingress: design movement joints in large continuous areas, or between adjacent/different building components, to minimise the risk of damage to façade, weather seal, and waterproofing joints.	Pre-requisite	NA	√	Complied
b. For water ingress in precast joints – specify silicone or modified silicone sealant on exterior exposed joints, that is compatible and with non-detachment properties to the substrate.	1	Cat 1	√	<u>1</u>
c. For efflorescence: Specify clear coat with good resistance to water absorption on façade surface. E.g. in	1	Cat 1	×	0

the case of exposed or pigmented concrete surfaces. *(OR)* Specify paint with good resistance to water absorption complying to SS500 or equivalent.				
1.4.2 Reduce risk of façade flaking/peeling/cracking/blistering (Up to 2 points)	Points	Assessment Category	**Used in Project**	**Points Scored**
a. Specify for integral colours (i.e. directly mixed into the cement) or post-applied stains (impregnator) with inorganic pigments for surfaces which do not require repainting.	2	Cat 2	√	40% * 2 = <u>0.8</u>
b. Specify paint finish: Topcoat: Paint with good resistance to water absorption complying to SS500or equivalent *(OR)* Mineral paint	1	Cat 2	×	0
Score for *1.4 Masonry and Lightweight Concrete Panels*				1 + 0.8 = 1.8 <u>1.6 (max)</u>

The final points for the entire Part B : ***Façade System (Metal Cladding + Curtain wall glazing + Masonry and light weight concrete panels)*** = 0.36 + 1.68 + 1.6 = **<u>3.82 pts</u>** + **<u>0.18 pts (bonus*)</u>**

The bonus points of **<u>0.18</u> is not be limited by the maximum cap under 1.2 Cladding; rather it is considered as additional points.*

1.5. FAÇADE FEATURES / OTHER FAÇADE CONSIDERATIONS (3 points)

1.5.1 Direct access to all protruding façade features, e.g. canopies, sunshades, niches, fins, ledges, BIPV, façade screens, etc.

Intent

To ensure safe and efficient access to facilitate cleaning, maintenance, and inspection of all façade features e.g. canopies, sunshade, niches, fins, ledges, photovoltaic panels, BIPV etc.

Design strategy and assessment: (prerequisite)

a. Ensure every part of all façade features is accessible for maintenance.

Note: Sole use of rope access is deemed unacceptable unless proven otherwise.

Documentation requirements

Design stage

- Plan/elevation/schematic drawings demonstrating all façade features is 100 % accessible through one or a combination of access systems. Please refer to BCA's façade access design guide[14] for more details on the submittals.

Verification stage

- Maintenance strategy report for façade access indicating access to façade features.

Design strategy and assessment: (prerequisite)

b. Ensure all glass features and their structures (e.g. glazed canopies) can withstand the maintenance-related loads.

Note: provide fall and drainage to mitigate water ponding and stagnation of dirt.

Documentation requirements

Design stage

- PE declaration indicating maintenance load has been accounted for in structural design.

Verification stage

- PE declaration form.

[14] Refer to BCA Façade Access Design Guide to provide required details on Façade access strategy, façade features etc. https://www1.bca.gov.sg/docs/default-source/docs-corp-buildsg/sustainability/dm_fadg_2017.pdf

1.5.2. Reduce risk of corrosion of exposed steel structures, e.g. linkways. (1 point)

Intent

To reduce the frequency of maintenance and repair of steel structures exposed to natural surrounding environment through optimal detailing

Design strategy and assessment: (1 point)

a. **Design to avoid direct contact of a steel base with the ground (raised by at least 100 mm) to mitigate corrosion and entrapment of moisture and dirt.**[15]
For example - Protect steel bases at ground by providing a collar or upstand.

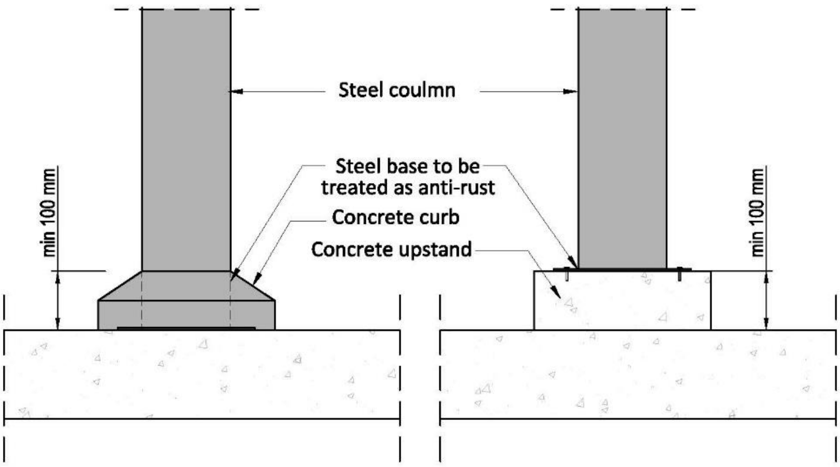


Figure 17: Concrete collar / upstand protection for steel base.

Documentation requirements

Design stage

- Plan drawings locating all steel structures with steel base protection.
- Detail drawings for steel base protection (minimum 100 mm above ground).

Verification stage

- As-built drawings/shop drawings to show implementation.
- Photographs of the concrete upstand or concrete curb after implementation.

[15] Reference BS EN 12944-3, www.steelconstruction.info

1.5.3. Reduce risk of water ingress in open joint cladding (i.e. cladding serving as a decorative feature, not as a water barrier) (1 point)

Intent

To ensure water tightness and minimise façade streaking to reduce the frequency of repair and maintenance by optimal design detailing and choice of materials.

Design strategy and assessment: (1 point)

a. **For features such as open-joint cladding: provide flashings at regular intervals not exceeding 3 floors to positively drain out the cladding cavities and prevent the accumulation of water.**

Documentation requirements

Design stage

- Plan/elevation drawings open joint cladding on the façade.
- Tender specification indicating use of flashings at regular intervals (not exceeding 3 floors) to drain out cladding cavities and prevent the accumulation of water.
- Detail drawings illustrating use of flashings on the cladding.

Verification stage

- As-built/shop drawings showing implementation
- Photographs of flashings on the open joint cladding after implementation.

1.5.4 Reduce risk of tile/stone from detaching off façade (up to 1 point)

Intent

To enhance public safety by reducing the incidence of dislodged tile and stone cladding through optimal detailing; and hence the frequency of maintenance and repair.

Design strategy and assessment: (1 point)

a. **Design for mechanically-fixed individual tile/stone panels with stainless steel fixings.**

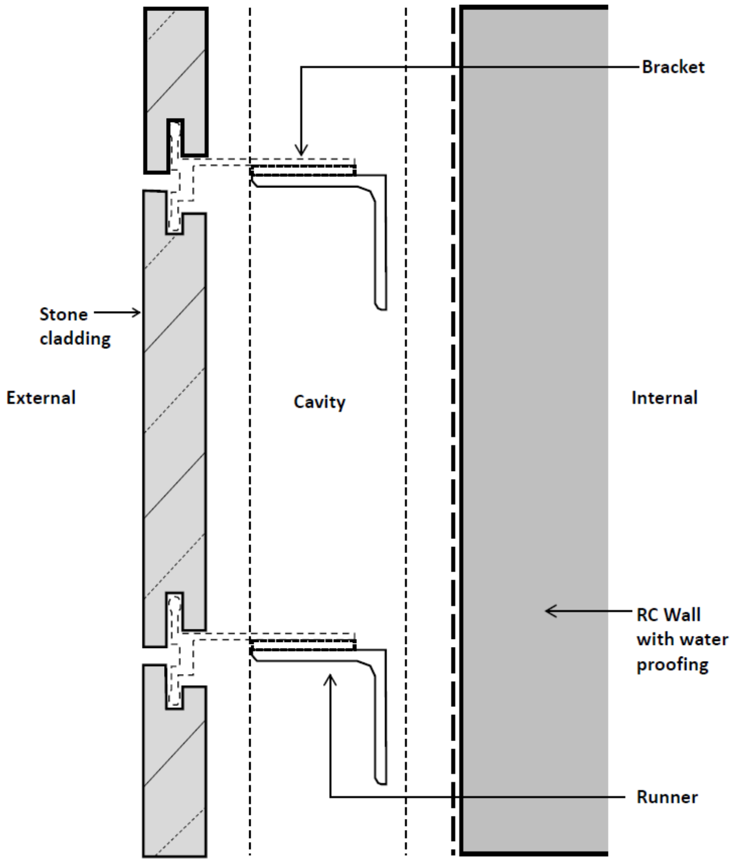


Figure 18: Illustration of mechanically-fixed stone cladding.

Documentation requirements

Design stage

- Plan/elevation drawings locating the tile and stone cladding façades using mechanically mounted panels.
- Tender specification indicating mechanically mounted, individual tile/stone panels with stainless steel fixings.
- Plan/elevation/section and detail drawings of mechanically mounted individual tile/stone panels with stainless steel fixings.

Verification stage

- As-built drawings (façade shop drawings) to show implementation.
- Product specification and delivery orders of the product.

1.6. ENTRANCE LOBBY (3 points)

1.6.1 Reduce risk of water ingress at entrances. (Up to 3 points)

Intent

To minimise water ingress at entrances caused by wind driven rains, through optimal design detailing to reduce the frequency of maintenance.

Design strategy and assessment: (prerequisite)

a. Design for raised internal level by at least 100 mm from the external datum.

Note: Use of ramps is encouraged for those who are differently-abled and delivery; with appropriately designed slope adhering to BCA guidelines on accessibility[16].

The external datum refers to a point – immediately adjacent to the internal level – that is exposed to rain and where runoff could accumulate and potentially flow into the building.

Documentation requirements

Design stage

- Plan drawings showing level changes at all building entrances from external datum.
- Detail section drawings indicating the level change (minimum 100 mm) at all building entrances.

Verification stage

- As-built drawings to show implementation.

[16] Refer to ramp gradients stated in BCA Accessibility Code

Design strategy and assessment: (Up to 2 points)

b. **Design canopy/overhang (with minimally 1:50 slope) to shelter against wind-driven rain with canopy angled at maximum 45 degrees to the entrance line and with drop panel if canopy/overhang does not shelter to entrance line.**

Note: The above gradient of 1:50 is indicative. Designers may propose alternative gradients to meet the intent of effective water drainage.

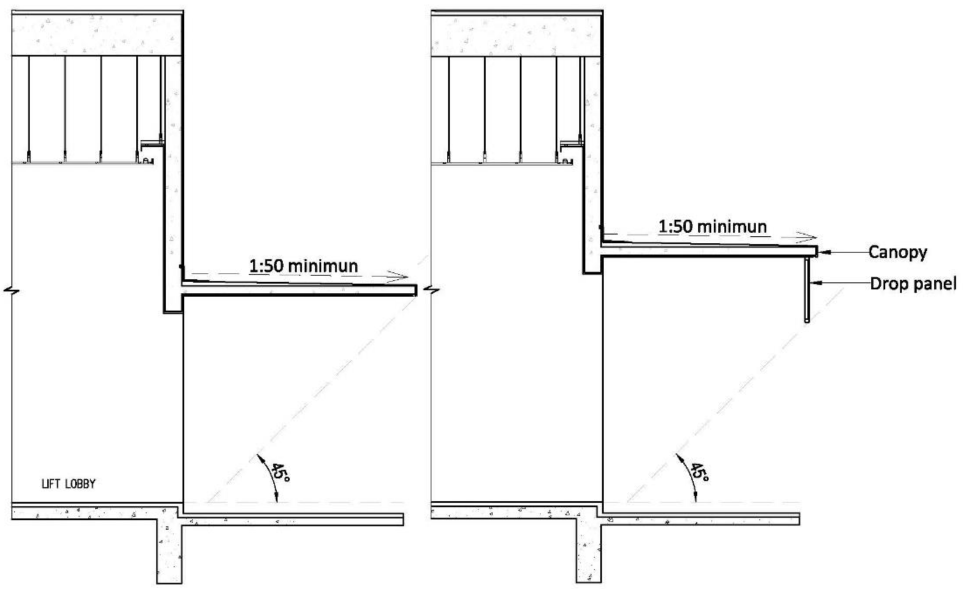


Figure 19: Design of canopy overhang (left), Design of canopy overhang with drop panel (right)

Life cycle cost analysis: Baseline vs Design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
1X - 1.1X	65% - 70%	20% - 25%	10 - 11

Baseline design strategy: Poorly designed canopy without brush mats
Proposed design strategy: Canopy (adequately designed to prevent wind driven rain)
Study period: 30 years
Yearly labour savings: 60-70% man-hour.

Advanced effort: (Bonus 1 point)

Advanced efforts: Numerical simulation studies (wind-driven rain penetration) studies specific to location, context of surroundings of entrances

Documentation requirements

Design stage

- Plan drawings locating the canopy/overhang at proposed building entrances.
- Plan/section/elevation showing canopy/overhang design and slope to fall at proposed entrance locations.
- Simulation studies and reports conducted for design improvement for advanced efforts.

Verification stage

- As-built drawings/shop drawings to show implementation.

Design strategy and assessment: (2 points)

c. Design entrances with transition/buffer zone, e.g. vestibule design
*(Solution c & d work as an integrated system and are not mutually exclusive, i.e. both needs to be scored.)***.**

Life cycle cost analysis: Baseline vs Design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
1.3X - 1.4X	45% - 50%	Up to 5%	20 - 21

Baseline design strategy: Poorly designed canopy without brush mats
Proposed design strategy: Entrance with vestibule design
Study period: 30 years
Yearly labour savings: 60-70% man-hour.

Documentation requirements

Design stage

- Plan drawings locating transition/buffer zone.
- Section/elevation drawings showing transition/buffer zone with drain pans, brush mat gratings, and walk-off mats at proposed building entrances.

Verification stage

- As-built drawings/shop drawings to show implementation.
- Photographs illustrating the buffer zone.

Design strategy and assessment: (1 point)

d. Design for aluminium drain pan with walk-off mats.
(Solution d must be integrated with solution b or c to be eligible for scoring.)

Note:
- *By understanding factors such as traffic type, flow and environment, entrance matting specification can be determined.*
- *Length of matting considered should be based on the number of people entering a premises per hour or per day.*

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
5% - 10%	25% - 30%	15% - 20%	3 - 4

Baseline design strategy: Poorly designed canopy without brush mats
Proposed design strategy: Poorly designed canopy with aluminium brush mats
Study period: 30 years
Yearly labour savings: 50-60% man-hour savings

Documentation requirements

Design stage

- Plan drawings locating aluminium drain pans with brush mat gratings and walk-off mats at proposed building entrances.
- Section/elevation drawings showing aluminium drain pans with brush mat gratings and walk-off mats at proposed building entrances.

Verification stage

- Photographs showing aluminium drain pan.

1.7 ROOF

1.7.1 Reduce risk of water ponding on roofs (prerequisite)

Intent

To reduce frequency of maintenance and repair of roof due to damage caused by water ponding, through optimal choice of material and detailing.

Design strategy and assessment: (prerequisite)

a. For concrete flat roofs - design slope not gentler than 1:150 and with scupper drains/gutter.

Note:

- *Consider siphonic drainage system for quick and efficient water draining.*
- *The above gradient of 1:150 is indicative. Designers may propose alternative gradients to meet the intent of effective water drainage.*

Documentation requirements

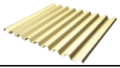
Design stage

- Plan drawings indicating the slope with scupper drains/gutter for concrete roofs.

Design strategy and assessment: (prerequisite)

b. For metal sheet profiles:
Design slope to manufacturer's specification
(OR)
Design slope for different sheet profiles based on the roof pitch table.
(OR)
Design slope for different sheet profiles determined by rainwater drainage capacity calculation.

Note: Minimum pitch has an important influence on the life expectancy of the product.

Metal Roofing Profile	Image	Minimum Rib to Rib Distance (mm)	Minimum Rib Height (mm)	Minimum Roof Pitch without end-lap (degree)	Minimum Roof Pitch with end-lap (degree)
Pierce-Fixed Profile		87.5	24	3	5
		190.0	29	3	5
Concealed-Fixed Profile		203.0	41	2	3
		300.0	27	7.5	7.5

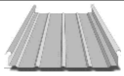
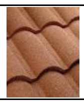
		320.0	25	7.5	7.5
		290.0	25	3	5
Standing Seam Profile		315	32	3	5
		415	65	2	3
Shingle Profile		N.A.	N.A.	15	15

Table 8- Roof pitch based on profile

Documentation requirements

Design stage

- Plan drawing locating metal roofs.
- Tender specification indicating the slope of metal sheet profile based on manufacturer's specification (OR) roof pitch table (OR) determined by rainwater drainage capacity calculation.
- Plan/section drawings indicating the slope.

Verification stage

- As-built drawings/shop drawings to show implementation.

1.7.2 Reduce risk of waterproofing decay / failure on concrete roofs. (prerequisite)

Intent

To reduce the frequency of maintenance and repair of concrete roofs through optimal choice of materials and design detailing.

Design strategy and assessment: (prerequisite)

a. **Specify bitumen/polymer elastomer preformed waterproofing membrane *(design for overlap and proper termination of waterproofing membrane).***

   (OR)

   Specify water-based/solvent-based liquid applied waterproofing membrane.

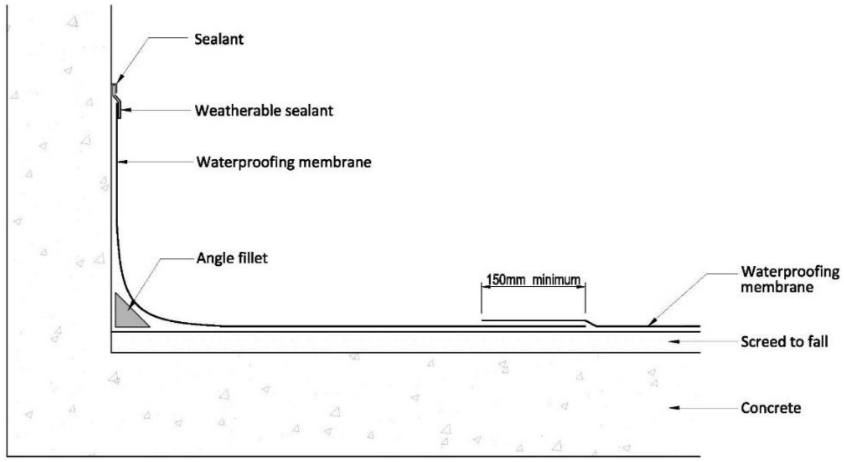


Figure 20: waterproofing termination and overlapping detail

Documentation requirements

Design stage

- Plan drawings with indication of all concrete roofs with exposed waterproofing.
- Detail drawings illustrating overlap and termination of waterproofing details.

Verification stage

- Photographs showing implementation.

1.7.3 Reduce risk of corrosion on metal roofs (prerequisite)

Intent

To reduce the frequency of maintenance and repair of metal roof structures by improving its durability through optimal choice of materials.

Design strategy and assessment: (prerequisite)

a. **Specify metal of similar properties or separators between different materials to mitigate risk of bi-metallic corrosion between roof and other metal components or accessories.**

Note: Refer to the table below for compatibility of metal with other metal accessory and materials.

Material	Accessory or Fastener Material					
	Zn-coated steel & zinc	Stainless Steel (300series)	AM-coated steel	Aluminium	Copper, Brass, Lead & Monel	Carbon Black ^
steel†	Yes*	No	Yes	Yes	No	No
Stainless steel	No	Yes	No	No	No	No
AM-coated steel	Yes*	No	Yes	Yes	No	No
Zn-coated steel & zinc	Yes	No	Yes*	Yes*	No	No

* Inert catchment situation may apply.
† Includes all prepainted products on an aluminium/zinc/magnesium alloy-coated steel or zinc-coated steel base
AM-coated steel = aluminium / zinc / magnesium alloy-coated steel
Zn-coated steel = zinc-coated steel
^ As found in some washers, roof penetration flashings and black "lead" pencils etc.

Table 9- Compatibility of direct contact between metals or alloys

Note: Careful prevention of swarf (steel debris arising from cutting or piercing operations when using friction saws, abrasive discs, drills, etc) staining (elaborate) is necessary during installation. Swarf particles, if left on the surface, will corrode and cause rust stains which will detract from the finished appearance of the product.

Documentation requirements

Design stage

- Tender specification indicating use of metal components with similar properties on the roof system based on manufacturer's recommendation or based on compatibility of direct contact of metal and alloys.

Verification stage

- Delivery order

SECTION 2 – ARCHITECTURAL INTERIOR

2.1 FLOORS (2.5 points)

2.1.1 Reduce risk of damage to floors in common areas within the building (1.5 points)

Intent

To reduce the frequency of repair and replacement to floorings due to wear and tear, though optimal selection of materials.

Design strategy and assessment: (1.5 points)

a. **Specify flooring materials with minimum Mohs[17] hardness value of 7, in areas of high pedestrian traffic such as entrances, lobbies, corridors and connecting walkways.**

Note: Mohs scale represents the mineral hardness of a material surface. The tile's surface resistance to wear and tear helps in reduced repair and replacement. The selected tile should comply with ASTM C1895 (additional info: or EN 15771 - Vitreous and porcelain enamels - Determination of surface scratch hardness according to the Mohs scale) for Mohs hardness value.

-Spaces with specific acoustic requirements maybe exempted despite being under the influence of the developer (ie. Auditorium, classrooms, cinemas etc.)

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental Cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
5% - 10%	75% - 80%	15% - 20%	2 - 3

Baseline design strategy: Ceramic tiles
Proposed design strategy: Full body porcelain tiles with Mohs value of minimum 7
Study period: 10 Years
Yearly labour savings: 70 - 80% man-hour savings.

Documentation requirements

[17] BCA – Good Industry Practices - Tiles with hardness value of 7 or higher are normally acceptable for most commercial applications or heavy traffic areas.

The first step to be assessed for this criterion is to scope up the spaces that constitute common areas. This would differ from buildings to buildings. As a rule of thumb, common areas refer to spaces that are within the influence of developers/owners.

Design stage

- Tender specification indicating the type of flooring material and the minimum Mohs hardness value.
- Plan drawing showing the location and extent of application of the specified floor finish.

Verification stage

- As-built (interior) drawings to show the extent of implementation.
- Relevant technical material specification or product performance test results indicating the specified Mohs hardness value.
- Delivery order for the specified product.

Worked Example 2a:

Hotel Hibiscus is an 18-storey 3-star hotel in Singapore is designed with 600 guest rooms. It has a main reception lobby to welcome guests, 3 ballrooms and a few large meeting rooms and executive lounges that are available for corporate and public booking.

The common areas in the hotel room are designed with a mix of carpet and homogenous flooring, and have a total floor area of 4,000m^2, comprising:

- 400m^2 of entrance lobby
- 2,500m^2 ballrooms
- 150m^2 of lift lobbies
- 450m^2 of common corridors
- 500m^2 meeting rooms and executive lounges

The breakdown of which is shown in Area Table II below:

NOTE: *The spaces below are within the scope of common areas as they fall under the influence of a developer. Though the guest rooms also fall under the influence of the developer/operator, they are not considered to have high pedestrian traffic, hence not considered for assessment.*

However, even as ballrooms, meetings rooms & executive lounges, and common corridors would fall under the influence of the developer, the use of carpets in these areas are necessary for its acoustic property in this context. As such, they will not be considered for assessment.

	Carpet (m^2)	Homo. Tiles (m^2)	Total (m^2)
Entrance Lobby	0	400	400
Ballrooms	2500	0	NA
Lift lobbies	0	150	150
Common Corridors	450	0	NA
Meeting Rooms & Exec. Lounges	500	0	NA
TOTAL (AREA FOR ASSESSMENT)			550

Area Table II : Breakdown of Flooring System

- Total applicable floor area for assessment
  = 550m^2

- Proportion of homogenous tiles to floor area
  = 550m^2 / 550m^2 = 100% ($\geqslant$15%)

2.1.1 Reduce risk of damage to floors in common areas within the building

2.1.1 Reduce risk of damage to floors in common areas within the building (1.5 points)	Points	Assessment Category	**Used in Project**	**Points Scored**
a. Specify flooring materials with minimum Mohs hardness value of 7, at areas of high pedestrian traffic such as main entrances, lobbies, corridors and connecting walkways.	1.5	Cat 1	√	100% * 1.5 = 1.5

**carpet does not meet the criteria of Mohs hardness value and hence is unable to score here*

2.1.2 Reduce maintenance works in common areas within the building (1 point)

Intent

To reduce the frequency of maintenance of floorings due to stains through optimal selection of materials.

Design strategy and assessment: (1 point)

a. **Specify flooring material – e.g. homogenous tiles – with water absorption rate not exceeding 0.5 % to reduce settling of stains at in areas of high pedestrian traffic such as entrances, lobbies, corridors and connecting walkways.**

Note: Water absorption rate indicates how much moisture a specific material is likely to absorb. Tiles with lower water absorption rate absorbs lesser stains and makes it easier for maintenance. The selected tile should comply with ASTM C373 for the water absorption test.

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental Cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
10% - 15%	15% - 20%	15% - 20%	3 - 4

Baseline design strategy: Carpet
Proposed design strategy: Vinyl Floor
Study period: 10 Years
Yearly labour savings: 20 - 30% man-hour savings.

Documentation requirements

The first step to be assessed for this criterion is to scope up the spaces that constitute common areas. This would differ from buildings to buildings. As a rule of thumb, common areas refer to spaces that are within the influence of developers/owners.

Design stage

- Tender specification indicating the flooring materials with maximum water absorption rate.
- Plan drawing showing the location and extent of the application.

Verification stage

- As-built (interior) drawings to show the extent of implementation.
- Relevant technical material specifications or product performance test results indicating the water absorption value of not more than 0.5%.
- Delivery order for the specified product.

Worked Example 2b:

Hotel Hibiscus' spaces that have been designed with homogenous floor tiles are observed to have scored for the following:

2.1.2 Reduce maintenance works for buildingfloors in common areas within the building

2.1.2 Reduce maintenance works for floors in common areas within the building(1 point)	Points	Assessment Category	**Used in Project**	**Points Scored**
a. Specify flooring material – e.g. homogenous tiles – with water absorption rate not exceeding 0.5 % to reduce settling of stains at areas of high pedestrian traffic such as entrances, corridors and lift lobbies.	1	Cat 2	√	18% * 1 = 0.18

** carpet does not meet the criteria for water absorption rate, hence is unable to score here.*

The total points for ***2.1 Floors*** (2.1.1 + 2.1.2) = 0.20 + 0.18 = 0.45 points

2.2 CEILINGS (4 points)

2.2.1 Access to services within double slab areas for maintenance purposes (2 points)

Intent

To ensure ease of access within double slabs for safe, efficient maintenance of services and equipment therein.

Design strategy and assessment: (prerequisite)

a. Provide double slabs with minimum clear headroom of 1.8 m.

Note:

- *Avoid using the area as storage which becomes obstacles for maintenance workers.*
- *Adequate lighting should be provided within double slab*
- *Consider adequate fall and drainage to avoid risk of water ponding from possible leakages.*

Documentation requirements

Design stage

- Tender drawings (plan and section) highlighting the clear headroom space of 1.8m for areas with double slab.

Verification stage

- As-built drawings to show the double slab and the clear headroom space.

Design strategy and assessment: (2 points)

b. Provide double slabs with minimum clear headroom of 2 m.

Note:

- *Avoid using the area as storage which becomes obstacles for maintenance workers.*
- *Adequate lighting should be provided within double slab*
- *Consider adequate fall and drainage to avoid risk of water ponding from possible leakages.*

Documentation requirements

Design stage

- Tender drawings (plan and section) highlighting the clear headroom space for areas of double slab.

Verification stage

- As-built drawings to show the double slab and the clear headroom space.

Worked Example 3a:

Rosebay Towers is a 15-storey office building has a GFA of 25,000 m^2 with multi-tenanted office spaces, a main reception and a drop-off porch for guests. It also has several accompanying facilities such as meeting rooms, a F&B area as well as sky terraces on the 4th, 8th and 14th storey.

The F&B area is a tenanted zone and is located on the 1st storey and it has a ceiling area of 1,200m^2. Access has been provided to all parts of the ceiling for general maintenance. There are double slab areas provided by the developer above the F&B areas due to code requirement. To allow for maintenance access within the double slab areas, 50% of this area has a 1.8m clear headroom, while the remaining 50% of the ceiling has a clear headroom of 2.0m.

NOTE: *Though the F&B area is a tenanted, double slab provisions are under the jurisdiction of the developer and hence are applicable for assessment.*

- Proportion of double slabs with 2m clear headroom
  = 50% (≥15%)

2.3.1 Access to services within double slab areas for maintenance purposes

2.3.1 Access to services within double slab areas for maintenance purposes. (2 points)	Points	Assessment Category	**Used in Project**	**Points Scored**
b. Provide double slabs with minimum clear headroom of 2 m	2	Cat 2	√	50% * 2 = 1
Score for 2.3.1 for double slab areas				1

2.2.2 Access to services within the ceiling in non-tenanted indoor spaces (up to 1 point)

Intent

To ensure ease of access within the ceiling for efficient maintenance of services and equipment therein.

Design strategy and assessment: (1 point)

a. **Specify open ceiling design.**

Documentation requirements

The first step to be assessed for this criterion is to scope up the spaces that constitute non-tenanted spaces. This would differ from buildings to buildings. As a rule of thumb, these would refer to spaces that are within the influence of developers/owners.

Design stage

- Tender specification indicating the open ceiling plan for the selected areas.
- Reflected ceiling plans showing the extent of open ceiling.

Verification stage

- As-built (interior) drawings to show implementation.
- Photographs of completed works highlighting the open ceiling.

Design strategy and assessment: (0.5 point)

b. **Specify suspended modular ceiling system that is easily demountable.**

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental Cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
10% - 15%	90% - 95%	Up to 5%	7 - 8

Baseline design strategy: Monolithic plaster ceiling
Proposed design strategy: Suspended mineral fibre grid ceiling
Study period: 10 Years
Yearly labour savings: 90 - 100% man-hour savings.

Documentation requirements

The first step to be assessed for this criterion is to scope up the spaces that constitute non-tenanted spaces. This would differ from buildings to buildings. As a rule of thumb, these would refer to spaces that are within the influence of developers/owners.

Design stage

- Tender specification indicating the type of false ceiling panel.
- Reflected ceiling plan showing the extent of the false ceiling and typical sectional drawing highlighting the demountable fixture details.

Verification stage

- As-built (interior) drawings to show implementation.
- Photographs of completed works showing the suspended modular ceiling panel.

Worked Example 3b:

Most of the office spaces in Rosebay Towers are tenanted except for the top 2 floors, the 14th and 15th storey, which are owned by the developer. The design of the top 2 floors of interior ceiling (office spaces) has total ceiling area of 3,000m², in a mix of suspended modular ceiling and open ceiling. The breakdown of the common spaces is tabulated below.

NOTE: *The spaces below are within the scope of common areas as they fall under the influence of the developer.*

	Monolithic Ceiling (m^2)	Suspended Modular Ceiling (m^2)	Open Ceiling (m^2)	Total (m^2)
Office Spaces (Developer-owned)	0	1000	2000	3000
Meeting rooms (Developer-owned)	0	200	0	200
Main Reception	300	0	0	300
Lift Lobbies & Corridors	500	0	0	500
TOTAL	800	1200	2000	4000

Area Table III : Breakdown of Ceiling Systems in indoor spaces

- Total interior ceiling area for common areas
  = 3,000m^2 + 200m^2 + 300m^2 + 500m^2 = 4,000m^2

- Proportion of open ceiling
  = 2,000m^2 / 4,000m^2 = 50% (≥15%)

- Proportion of suspended modular ceiling
  = 1,200m^2 / 4,000m^2 = 30% (≥15%)

2.2.2 Access to services within the ceiling in non-tenanted indoor spaces.

2.2.2 Access to services within the ceiling in non-tenanted indoor spaces. (up to 1 point)	Points	Assessment Category	**Used in Project**	**Points Scored**
a. Specify open ceiling design	1	Cat 2	√	50% * 1 = 0.50
b. Specify suspended modular ceiling system that is easily demountable.	0.5	Cat 2	√	30% * 0.5 = 0.15
		Score for 2.3.2	0.5 + 0.15 = 0.65	

**Monolithic ceiling does not meet the criteria.*

2.2.3 Access to ceiling for maintenance (prerequisite)

Intent

To ensure ease of access to ceiling for safe and efficient maintenance.

Design strategy and assessment: (prerequisite)

a. **Provide access to all parts of ceilings** *(including weather-exposed ceilings)* or exposed soffit (where there are no ceilings) **for general maintenance.**

Note:

- *Avoid use of scaffolding as an access strategy.*
- *Ceilings using mobile elevated working platform (MEWP), must ensure obstruction-free access to all parts of the ceiling.Areas with permanent tiered seatings may be excluded for assessment (e.g. auditoriums, concert halls.)*
- *Access to Lightings and smoke detectors will be assessed here.*

Documentation requirements

Design stage

- Schematic drawings (plan/elevation/section) demonstrating entire false ceiling system is 100% accessible through one or combination of access systems.

Verification stage

- Extract from maintenance strategy report indicating the provision of access.

2.2.4 Reduce risk of warping / deterioration of ceiling panel systems that are weather-exposed, e.g. sky terraces, entrance porches, corridors, and canopies (up to 1 point)

Intent

To reduce frequency of repair and replacement of weather-exposed ceiling panels through optimal selection of materials.

Design strategy and assessment: (1 point)

a. **Specify suspended metal panel modular ceiling system, e.g. baffle metal panels and metal mesh panels.**

Note:

- *Panels should be designed to prevent sagging and withstand wind loads.*
- *Panels should be sized such that they can be easily handled by one person.*

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental Cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
40% - 45%	75% - 80%	5% - 10%	6 - 7

Baseline design strategy: moisture-resistant monolithic plaster ceiling (gypsum board)
Proposed design strategy: Metal Panel Modular Suspended Grid ceiling
Study period: 10 Years
Yearly labour savings: 90 - 100% man-hour savings.

Documentation requirements

The first step to be assessed for this criterion is to scope up the ceiling spaces in weather-exposed areas.

Design stage

- Tender specification indicating the type of metal suspended modular ceiling panel.
- Reflected ceiling plans showing the extent of metal false ceiling.

Verification stage

- As-built (interior) drawings showing the extent of implementation.
- Relevant technical material specification for the selected metal panel ceiling and the anti-corrosion property of the material.
- Delivery order for the selected ceiling panels.
- Photographs of completed works.

Design strategy and assessment: (1 point)

b. Specify moisture-resistant suspended non-metallic modular ceiling panels with water absorption rate not exceeding 5 %.

Note: Water absorption rate indicates how much moisture a specific material is likely to absorb. Ceiling panels with lower water absorption rate absorbs less moisture and are less prone deterioration. The selected ceiling panel should comply with ASTM C473 for the water absorption test.

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental Cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
15% - 20%	55% - 60%	10% - 15%	4 - 5

Baseline design strategy: Moisture Resistant monolithic plaster ceiling (gypsum board)
Proposed design strategy: Moisture resistant suspended grid ceiling (calcium silicate)
Study period: 10 Years
Yearly labour savings: 90% - 100% man-hour savings

Documentation requirements

The first step to be assessed for this criterion is to scope up the ceiling spaces in weather-exposed areas.

Design stage

- Tender specification indicating the moisture resistant material and maximum water absorption rate for suspended ceiling panel.
- Reflected ceiling plans showing the extent of the moisture-resistant false ceiling.

Verification stage

- As-built (interior) drawings to show the extent of implementation.
- Relevant technical material specification or product performance test results for the moisture resistant property of the ceiling panel for the water absorption rate.
- Photographs of completed works.

Design strategy and assessment: (1 point)

c. Specify for open ceiling design.

Documentation requirements

The first step to be assessed for this criterion is to scope up the ceiling spaces in weather-exposed areas.

Design stage

- Tender specification indicating the open ceiling system for the selected areas.
- Reflected ceiling plans showing the extent of open ceiling.

Verification stage

- As-built (interior) drawings to show implementation.
- Photographs of completed works showing the open ceiling spaces.

Worked Example 3c:

Rosebay Towers has a link bridge that connects the 2 blocks of the office units. The office building has 500m^2 of ceiling area that are weather exposed and are managed by the owner. These ceiling areas comprise of:

- 360m^2 of sky terraces designed with open ceiling, located on the 4th, 8th and 14th storey
- 80 m^2 of drop-off porch in modular metal panels
- 60m^2 of link bridge in open ceiling

The breakdown of which is shown in Area Table IV*Area Table III* below:

	Modular Metal Panel (m^2)	Open Ceiling (m^2)	Total (m^2)
Sky Terraces	0	360	360
Drop-off porch	80	0	80
Link Bridge	0	60	60
TOTAL	80	420	500

Area Table IV : Breakdown of Ceiling Systems in weather exposed spaces

- Proportion of modular metal panel
  = 80m^2 / 500m^2 = 16% (≥15%)

- Proportion of open ceiling
  = 420m^2 / 500m^2 = 84% (≥15%)

2.2.4 Reduce risk of warping / deterioration of ceiling panel systems that are weather-exposed

2.2.4 Reduce risk of warping/deterioration of ceiling panel system that are weather-exposed, e.g. sky terraces, entry porches, corridors and canopies. (up to 1 point)	Points	Assessment Category	**Used in Project**	**Points Scored**
a. Specify suspended metal panel modular ceiling system, e.g. baffle metal panels and metal mesh panels.	1	Cat 2	√	16% * 1 = 0.16
b. Specify moisture-resistant suspended non-metallic modular ceiling panels with water absorption rate not exceeding 5 %.	1	Cat 2	×	0
c. Specify open ceiling design.	1	Cat 2	√	84% * 1 = 0.84
Score for 2.3.4 ceiling panel systems				0.16 + 0.84 = 1

As such, the total score for ***2.2 Ceilings*** (2.3.1 + 2.3.2 + 2.3.4) = 1 + 0.65 + 1 = 2.65 points

2.3 WET ROOMS AND STORAGE (8 points)

2.3.1 Provide permanent space to store cleaning tools and toilet supplies (up to 1 point)

Intent

To improve maintenance efficiency through provision of storage by adopting appropriate design & detailing.

Design strategy and assessment: (1 point)

a. **Design for storage rooms for cleaning tools, carts, and supplies such as tissue rolls and soap refill for every male and female toilet cluster.**

Documentation requirements

Design stage

- Tender drawings (plan and elevation) showing the location of storage rooms for every male and female toilet clusters.

Verification stage

- As-built (interior) drawings to show implementation.
- Photographs showing the dedicated rooms for storage.

Design strategy and assessment: (0.5 point)

b. **Design for at least one storage space within the male and female toilet clusters to store supplies such as tissue rolls and soap refill.** (Point cannot be scored if already scored for solution a)

Documentation requirements

Design stage

- Tender drawings (plan) showing the location of storage space within every male and female toilet clusters for store supplies.

Verification stage

- As-built (interior) drawings to show implementation.
- Photographs of completed works showing the dedicated storage space.

2.3.2 Reduce risk of mould and fungus formation on walls in wet rooms (up to 1 point)

Intent

To reduce the frequency of repair and replacement of wall surfaces due to mould and algae formation, through optimal selection of materials.

Design strategy and assessment: (1 point)

a. Specify wall finishes with tiles e.g. glazed ceramic tiles or homogenous tiles[18] [19]

Note: The tiles considered are manufactured tiles, not natural stones.

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental Cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
2.1X - 2.2X	90% - 95%	25% - 30%	5- 6

Baseline design strategy: Standard paint with primer
Proposed design strategy: Tiled wall
Study period: 10 Years
Yearly labour savings: 80 - 90% man-hour savings.

Documentation requirements

Design stage

- Tender specification indicating the type of tile material used.
- Plan and section drawings showing the extent of wall finish.

Verification stage

- As-built (interior) drawings to show extent of implementation.
- Photographs of completed works.

Design strategy and assessment: (0.5 point)

b. Specify wall finishes with anti-mould top coat.

Note:

- *The surface preparation for the top coat must follow the method statement mentioned in SS542.*

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental Cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
Up to 5%	55% - 60%	35% - 40%	1 -2

Baseline design strategy: Standard paint with primer
Proposed design strategy: Anti-mould paint
Study period: 10 Years
Yearly labour savings: 20 - 30% man-hour savings.

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[18] Guide to Better Public Toilet Design and Maintenance, 1.3. Wall and floor tiles of large surface areas are encouraged for easy maintenance. The tile size should be at least 100mm by 200mm. Part III Maintenance Strategy Report, F2.1, “Use moisture impervious, durable (e.g. ceramic tiles and phenolic panels) and cleanable materials for toilet floor and wall surfaces, to facilitate cleaning and resource conservation.

[19] BCA – Good Industry Practices - Impervious tiles – Absorbs water between 0 and 0.5% of its weight.

Documentation requirements

Design stage

- Tender specification indicating anti-mould paint finish as top coat.
- Plan and typical sectional drawings showing the extent of application.

Verification stage

- As-built (interior) drawings to show extent of implementation.
- Relevant technical material specification on anti-mould property of the selected paint finish.
- Delivery order for the specified paint finish.

Worked Example 4:

A primary school has staff and student toilets with a wall height of 2.5m, measured from the finished floor level to the false ceiling. All the walls have been designed with wall tiles up to 2.0 m above floor level while the remaining wall area is coated with plaster and paint with anti-mould properties.

The primary school wall area is designed with:

- A total wall area of 1,100m^2
- 1,050 m^2 of male and female staff toilets, across 7 clusters
- 50m^2 of accessible toilet

As such:

- Area of wall tiles
  = (2.0m/2.5m) * 1,100m^2 = 880m^2

- Proportion of wall tiles
  = 880m^2/1,100m^2 = 80% (≥15%)

- Area of plaster and paint with anti-mould
  = 1,100m^2 – 880m^2 = 220m^2

- Proportion of plaster and paint with anti-mould
  = 220m^2 / 1,100m^2 = 20% (≥15%)

<u>2.3.2 Reduce risk of mould and fungus formation on walls in wet rooms</u>

2.3.2. Reduce risk of mould and fungus formation on walls in wet rooms (up to 1 point)	Points	Assessment Category	**Used in Project**	**Points Scored**
a. Specify wall finishes with tiles e.g. glazed ceramic tiles and homogenous tiles.	1	Cat 2	√	80% * 1 = <u>0.8</u>
b. Specify wall finishes with anti-mould top-coat	0.5	Cat 2	√	20% * 1 = <u>0.2</u>
Score for 2.4.3 walls in wet rooms				0.8 + 0.2 = <u>1</u>

The total points for *2.3.2 under Wet Rooms & Storage* is = <u>1 point</u>

2.3.3 Reduce risk of damage to toilet cubicle partitions and enable ease of cleaning (1 point)

Intent

To reduce the frequency of repair and replacement of toilet partitions due to damage, through optimal selection of materials and design & detailing**.**

Design strategy and assessment: (0.5 point)

a. **Specify water-resistant, partition panels with water absorption rate not exceeding 5 %, e.g. phenolic panels.[20]**

Documentation requirements

Design stage

- Tender specification indicating the maximum water absorption rate of the material.
- Plan and sectional drawings showing the location of application.

Verification stage

- As-built (interior) drawings to show implementation.
- Relevant technical material specification or product performance test results for the rate of water absorption for the selected product.

Design strategy and assessment: (0.5 point)

b. **Design for raised partition walls with minimum of 50 mm gap[21] from the finished floor level**.

Documentation requirements

Design stage

- Tender drawings (plan and section) indicating the raised partition walls with at least 50 mm gap from the finished floor level.

Verification stage

- As-built (interior) drawings to show implementation.
- Photographs highlighting the implemented raised partition panels.

---

[20] Guide to Better Public Toilet Design and Maintenance, 1.3 Materials, "Materials used should be durable, easy to maintain and resistant to vandalism and neglect. For all wall finishes, it must be of materials which are impervious, durable such as ceramic tiles and phenolic panels etc which can facilitate cleaning and resource conservation (such as minimising the use of water and cleaning agents). This also applies to floors, which must be constructed of waterproof non- slip surfaces like ceramic tiles, natural stone, homogeneous tiles, terrazzo or other impervious materials, to facilitate cleaning and resource conservation."

[21] Guide to Better Public Toilet Design and Maintenance, 1.5 Water Closets (WCs), "Cubicle partitions must be of rigid design and wall or ceiling hung, where practical, without leg support for easy cleaning of the floor."

2.3.4 Reduce risk of water spill, splashing and soap dripping on the counter and floor (3.5 points)

Intent

To reduce the frequency of maintenance due to wet floors and counters, through appropriate design & detailing.

Design strategy and assessment: (1.5 points)

a. Water spill on floor - Design for full vanity washbasin to slope away from the user[22].

Documentation requirements

Design stage

- Tender specification indicating vanity wash basin.
- Plan, elevation, and sectional drawings showing full vanity washbasin set that meets the requirements.

Verification stage

- As-built (interior) drawings to show the implementation.
- Photographs of completed works.

Design strategy and assessment: (0.5 point)

b. Water spill on floor – Design for soap and tissue dispenser within arm's reach of each faucet[23].
(Points can be scored only after scoring solution (a))

Documentation requirements

Design stage

- Tender drawings (plan and typical sections) indicating the location of soap and tissue dispenser.

Verification stage

- As-built (interior) drawings to show implementation.
- Photographs of completed works.

Design strategy and assessment: (1 point)

c. Soap dripping on counter/floor – Design of soap dispenser location to be vertically mounted directly above basin or integrated bin.

Note: Soap dispensers fixed above the counter is easier to identify and refill as and when required.

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[22] Guide to Better Public Toilet Design and Maintenance, 1.6 Wash Basins, "All wash basins should be installed into vanity tops, and located beneath the vanity. Vanity tops should have backsplash and apron edges"

[23] Guide to Better Public Toilet Design and Maintenance, 1.7 Provision of Facilities, "A one-stop provision of auto sensor tap, auto sensor soap dispenser, litter bin and hand-dryer or paper towel dispenser at wash basin area is strongly recommended to minimise wetting of floors and provide the ease of keeping the toilet clean and dry."

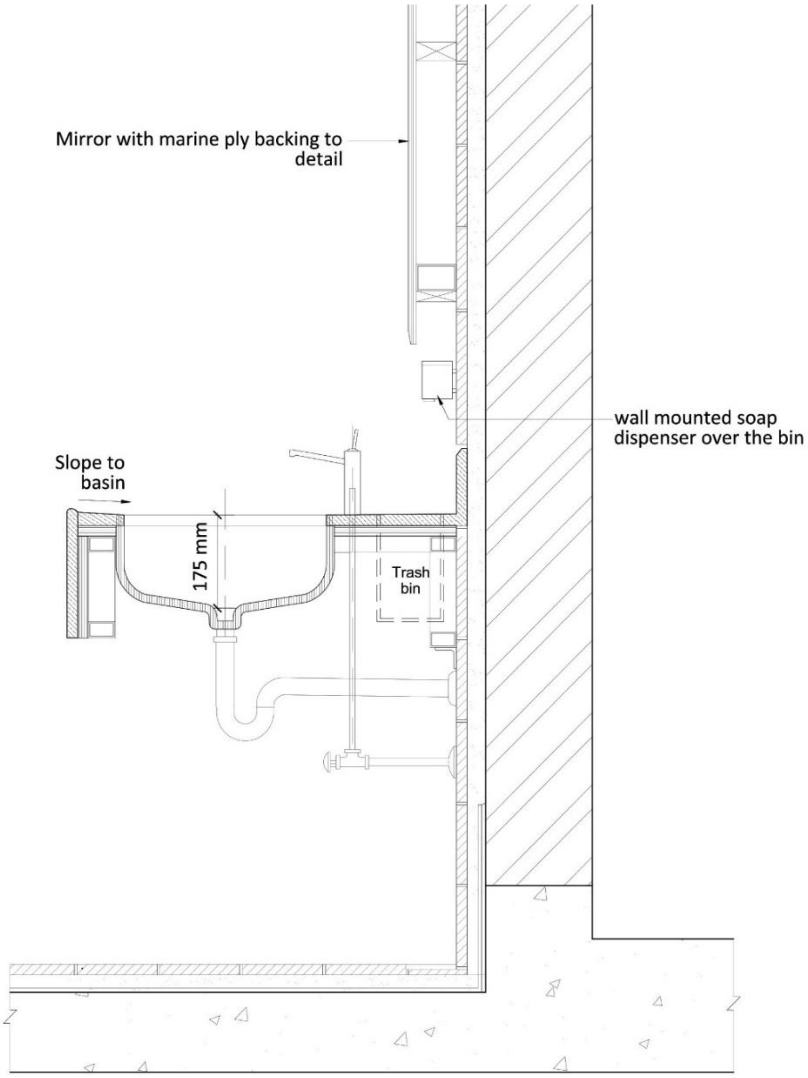

Figure 21 - Schematic sectional drawing with vanity basin

Documentation requirements

Design stage

- Tender drawings (plan, elevation, and typical sections) showing soap dispenser vertically mounted above the bin or basin.

Verification stage

- As-built (interior) drawings to show implementation.
- Photographs of completed works.

Design strategy and assessment: (0.5 point)

d. Water splash on counter/floor - Specify depth of basins to be minimally 175 mm to avoid excessive splashing.

Note: The use of flat bottom wash basins is not recommended[24].

Documentation requirements

Design stage

- Tender drawings (plan and typical section) indicating the wash basin counter design with the depth of the basin.

Verification stage

- As-built (interior) drawings to show implementation.
- Relevant technical specification showing the depth of the basin.

2.3.5 Reduce the need to replace entire mirror glass pane when damaged (0.5 point)

Intent

To ensure ease of replacement of damaged mirror glass panes, through appropriate design & detailing.

Design strategy and assessment: (0.5 point)

a. Design for individual, modular mirror panes with standard sizes that are easy to replace.

Documentation requirements

Design stage

- Tender drawings (elevation) showing individual, modular mirror panes.

Verification stage

- As-built (interior) drawings to show implementation.
- Photographs showing the mirrors in the toilet.

[24] Guide to better Public Toilet Design and Maintenance – Restroom Association (Singapore) 2018 - Section 1.6 Wash Basins and Shower taps. "The use of flat bottom wash basins is not recommended. Such wash basins do not effectively allow dirt and debris to be washed into the drain pipes."

2.3.6 Reduce degradation of false ceiling system in wet rooms (up to 1 point)

Intent

To reduce the frequency of repair and replacement of moisture-exposed ceiling panels through optimal selection of materials.

Design strategy and assessment: (1 point)

a. **Specify moisture-resistant, suspended non-metallic modular ceiling panels with water absorption rate not exceeding 5%.**

Note: Ceiling panels with lower water absorption rate absorbs less moisture and reduces deterioration. The selected ceiling panel should comply with ASTM C473 for the water absorption test.

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental Cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
15% - 20%	85% - 90%	10% - 15%	4 - 5

Baseline design strategy: Moisture resistant monolithic plaster ceiling
Proposed design strategy: moisture resistant suspended modular ceiling (Calcium Silicate)
Study period: 10 Years
Yearly labour savings: 90 - 100% man-hour savings.

Documentation requirements

Design stage

- Tender specification indicating the moisture resistant material and maximum water absorption rate for suspended ceiling panel.
- Reflected ceiling plans showing the extent of the moisture-resistant false ceiling.

Verification stage

- As-built (interior) drawings to show extent of implementation.
- Relevant technical material specification or product performance test results for the moisture resistance property of the ceiling panel with water absorption rate of 5% or lower.
- Photographs of completed works.

Design strategy and assessment: (1 point)

b. **Specify suspended metal panel modular ceiling system, e.g. baffle metal panels, aluminium trellis, and metal mesh.**

Documentation requirements

Design stage

- Tender specification indicating the type of metal suspended ceiling panel.
- Reflected ceiling plans showing the metal modular ceiling.

Verification stage

- As-built (interior) drawings to show extent of implementation.
- Photographs of completed works.

Design strategy and assessment: (1 point)

c. **Specify for open ceiling design.**

Documentation requirements

Design stage

- Tender specification indicating the open ceiling system for the selected areas.
- Reflected ceiling plans showing the extent of open ceiling.

Verification stage

- As-built (interior) drawings to show implementation.
- Photographs of completed works showing the open ceiling spaces.

Worked Example 5:

A 5-storey shopping mall has toilets on every floor of the building. There are 10 clusters of toilets in the shopping mall. The ceiling area of the wet rooms and storage has a total ceiling area of 2500m^2, comprising:

- 240m^2 within each cluster of male, female toilets and an accessible toilet, with a total of 2400m^2 for all the 10 clusters of toilets, designed with metal mesh ceiling structures
- 10m^2 of janitor stores located adjacent to each cluster with a total of 100m^2, designed with moisture resistant ceiling panel in the shopping mall.

The breakdown of which is shown in Area Table V below:

	Suspended metal modular ceiling (metal mesh) (m^2)	Moisture resistant modular ceiling panel (m^2)	Total (m^2)
Male, Female & Accessible Toilet	2400	0	2400
Janitor Store	0	100	100
	2400	100	2500

Area Table V : Breakdown of Ceiling Systems in the toilets

- Proportion of suspended metal modular ceiling (metal mesh)
  = 2,400m^2 / 2,500m^2 = 96% (≥15%)

- Proportion of moisture resistant modular ceiling panel to total ceiling area in wet rooms
  = 100m^2 / 2,500m^2 = 4% (<15% of total ceiling area, it will not score any points.)

NOTE: *Under the assessment category of Cat 2, full points can be scored when proportion is >85%. Hence, the moisture resistant ceiling panel, which is 96% of total ceiling area, will score for 100% of the points.*

2.3.6 Reduce degradation of false ceiling systems in wet rooms

2.3.6 Reduce degradation of false ceiling system in wet rooms (up to 1 point)	Points	Assessment category	**Used in Project**	**Points Scored**
a. Specify moisture-resistant suspended non-metallic modular ceiling panels with water absorption rate not exceeding 5%.	1	Cat 2	√	100% * 1 = 1
b. Specify suspended metal panel modular ceiling system, e.g. baffle metal panels, aluminium trellis, and metal mesh.	1	Cat 2	√ (<15%)	0
c. Specify open ceiling design	1	Cat 2	ξ	0
Score for 2.4.6 walls in wet rooms				1 + 0 = 1

The total points for 2.3.6 *under Wet Rooms & Storage* is = 1 point

2.4 BASEMENTS (4 points)

2.4.1 Reduce risk of water ingress/seepage in basement (up to 4 points)

Intent

To reduce the frequency of repair and maintenance of basement structures due to water ingress, through optimal selection of materials and design & detailing.

Design strategy and assessment: (prerequisite)

a. Specify for positive side waterproofing on the retaining wall, e.g. sheet-membrane systems, vapour barriers or equivalent.

Documentation requirements

Design stage

- Tender specification indicating water proofing on positive side.
- Plan and sectional drawings showing the location of application.

Verification stage

- As-built (construction) drawings to show the extent of implementation.
- Delivery order for the specified waterproofing system.
- Photographs taken during implementation

Design strategy and assessment: (2 points)

b. Design for cavity wall with raised kerb of minimally 200mm and with water and mould -resistant wall layer on the inside, e.g. calcium silicate board/ concrete block masonry, etc.

Note:

- *The inside wall layer should possess water absorption rate not exceeding 5% and should comply with ASTM C473 standards for water absorption test.*
- *Access panel to be provided for periodic maintenance.*
- *Provision of drainage/weep hole along the wall is required as per consultant specification*[25]

[25] SS 637 :2018 Code of practice for waterproofing of reinforced concrete buildings, “three methods for water tightness, a) tanked protection – the protection depends on the application of a continuous waterproofing barrier system applied to the structure, b) structurally integral waterproofing – the protection depends on the ability of the concrete structure to minimize/ prevent water penetration, and c) drained protection – the protection depends on the provision of floor and wall cavity to collect and channel water out of basement” Depending on which system the Structural Engineer chooses, there are different design details to consider.

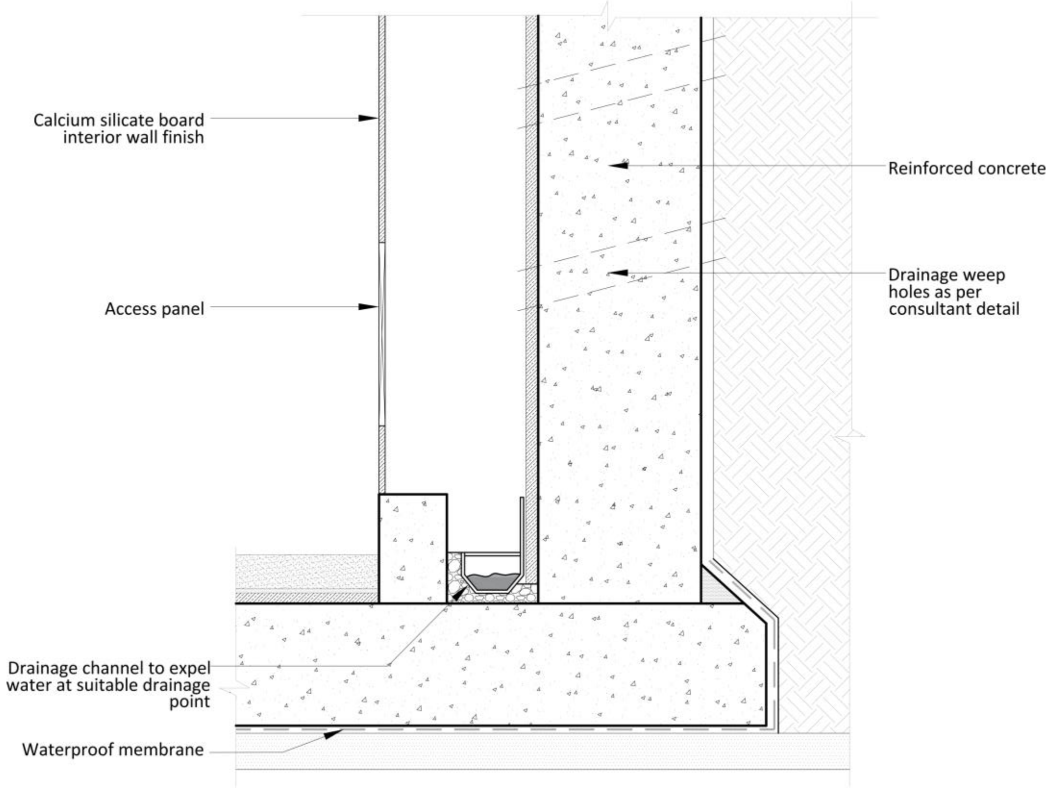

Figure 22 - Typical section of cavity wall with waterproofing

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental Cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
3.6X-3.7X	95% - 100%	30% - 35%	12 - 13

Baseline design strategy: RC Wall with only positive side waterproofing
Proposed design strategy: Cavity wall with raised curb
Study period: 30 Years
Yearly labour savings: 80 - 90% man-hour savings.

Documentation requirements

Design stage

- Tender specification indicating the type of water-resistant internal wall.
- Plan and sectional drawings showing the location of cavity wall and extent of application.

Verification stage

- As-built drawings to show extent of implementation.
- Relevant technical specification for the water-resistance property and water absorption rate for the selected internal wall.
- Photographs of completed works showing the basement cavity wall with access panel.

Design strategy and assessment: (1 point)

c. **Specify for positive side waterproofing for the base slab, e.g. sheet-membrane systems, vapour barriers or equivalent.**

Documentation requirements

Design stage

- Tender specification indicating water proofing on positive side.
- Plan and sectional drawings showing the type of waterproofing system.

Verification stage

- As-built (construction) drawings to show implementation.
- Delivery order for the specified waterproofing system.
- Photographs taken during implementation.

Design strategy and assessment: (1 point)

d. **Specify integral liquid water proofing admixture in the concrete.**

Documentation requirements

Design stage

- Tender specification indicating integral waterproofing admixture system.
- Plan and sectional drawings showing location of application.

Verification stage

- As-built drawings to show extent of implementation.
- Relevant technical specifications for the selected water proofing system.
- Delivery order for the specified water proofing admixture.

2.5 LOADING BAY/ BACK OF HOUSE SERVICE AREAS (2.5 points)

2.5.1 Reduce damage caused by impact on walls and columns in vehicular ramps and loading bay areas (prerequisite)

Intent

To reduce the frequency of repair and maintenance of damaged building elements, through optimal selection of materials.

Design strategy and assessment: (prerequisite)

a. **Specify wall bumpers, column guards, wheel stoppers and bollards.**

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental Cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
100% (No provision for baseline)	90% - 95%	80% - 85%	4 - 5

Baseline design strategy: No column guard
Proposed design strategy: With column guard and wall bumper
Study period: 30 Years
Yearly labour savings: 90 - 100% man-hour savings.

Documentation requirements

Design stage

- Tender specifications indicating the protection layer for walls and columns.
- Plan and typical sectional drawings showing the location of protective measures for loading bay/back of house service areas.

Verification stage

- As-built (construction) drawings to show implementation.
- Photographs of completed works.

2.5.2 Reduce damage to walls, columns and floors at back of house traffic delivery areas (2.5 points)

Intent

To reduce the frequency of repair and maintenance of damaged building elements, through optimal selection of materials.

Design strategy and assessment: (0.5 point)

a. Specify column guards in service delivery areas.

Life cycle cost analysis: baseline vs design strategy

Incremental Cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
100% (No provision for baseline)	90% - 95%	30% - 35%	6 - 7

Baseline design strategy: Concrete Block Wall with no additional protection
Proposed design strategy: Wall bumper and column guard
Study period: 10 Years
Yearly labour savings: 90 - 100% man-hour savings.

Documentation requirements

Design stage

- Tender specifications indicating the protective layer for walls, columns and floors.
- Plan drawing showing the location of protective measures for columns in high traffic areas.

Verification stage

- As-built (construction) drawings to show implementation.
- Photographs of completed works.

Design strategy and assessment: (2 point)

b. Specify protective materials:

i) for walls, floors and doors, e.g. chequered plate on walls (0.67 point)

ii) for floors, e.g. epoxy flooring (0.67 point)

iii) for doors, e.g. kick boards on doors (0.67 point)

Documentation requirements

Design stage

- Tender specifications indicating the protective materials for walls, floor, and doors.
- Tender drawings (plan and typical sections) showing the location of protective measures for walls, floors, and doors.

Verification stage

- As-built (construction) drawings to show implementation.
- Photographs of completed works highlighting the protective measures.

PART A: COOLING SYSTEMS – SECTION 3.1 to 3.2 (Up to 9.5 points)

(Points in 3.1 or 3.2 will be apportioned based on the installed capacity of chillers and VRF condenser units. Points will be prorated for projects served by District Cooling system)

3.1 CHILLER PLANT (9.5 points)

This section addresses the design solutions with respect to chiller plant main equipment such as chillers, pumps, cooling towers, and ancillary systems (e.g. sensors and actuators, water treatment system, ventilation provisions, and general pipe works). Access space provision must include routine inspection, cleaning, calibration, and possible future replacement.

Chiller plant equipment which shares common space for access and maintenance must comply with the following:

- Shared maintenance space is applicable if the adjacent equipment is not maintained simultaneously.
- The shared clearance must be equal or greater than the larger of those required.

The typical chiller plant room layout is shown in Figure 23.

Note:

- *The access space provisions stated in Figure 23 are applicable for commonly available equipment in the ACMV industry. However, designers should follow manufacturer's specified space requirement if the minimum access space is greater than the values stated in relevant sections.*
- *The pipe routing shown below is only indicative and designers must follow the least resistance path for optimal performance.*

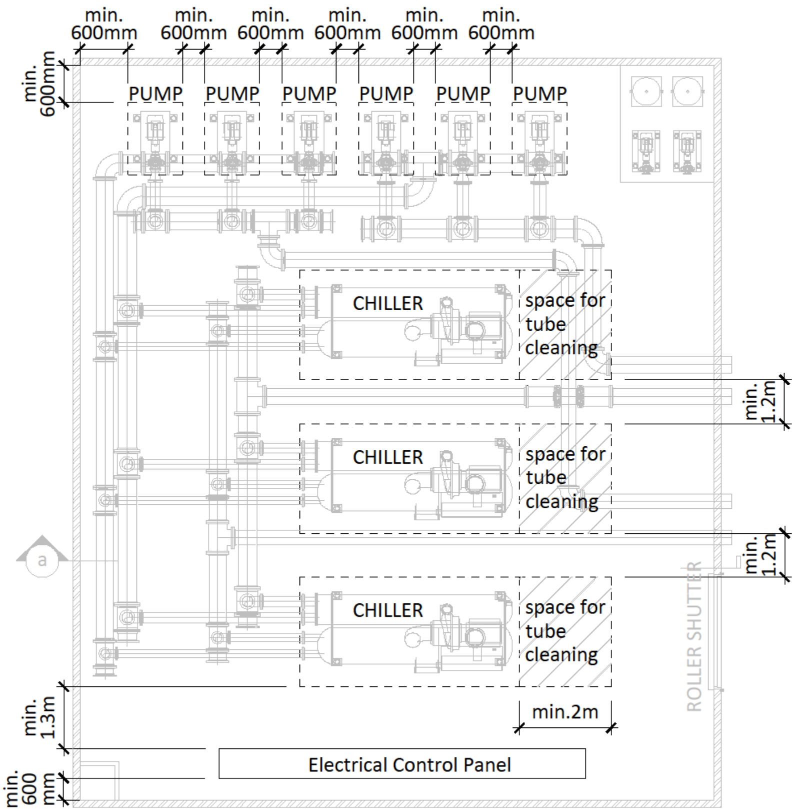

Figure 23: Typical chiller plant room layout and space provision

3.1.1 Access to chiller plant room for equipment replacement (prerequisite)

Intent

To provide adequate space for movement of chiller from the nearest entrance to the plant room (applicable for chiller plant room either at basement, service floor or roof top).

Design strategy and assessment: (prerequisite)

a. **Where chiller plant is located in the basement**
   i) **Provide direct access from driveway through operable openings (i.e. roller shutter).**
      (OR)
   ii) **Provide operable openings and service corridor with minimum width of 2.5 m which is directly accessible from the driveway.**

Note: Designers should follow the manufacturer's specified requirement if the minimum access space is greater than the above stated access requirements.

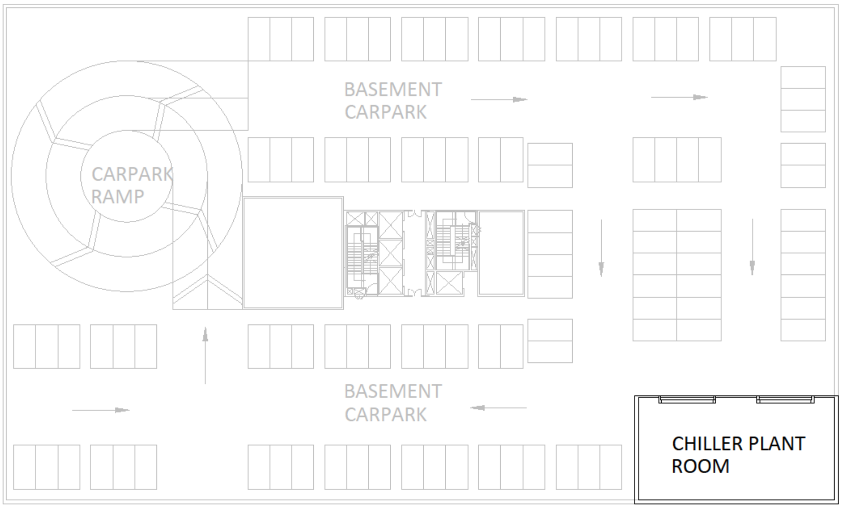

Figure 24: Basement chiller plant with direct access from drive way

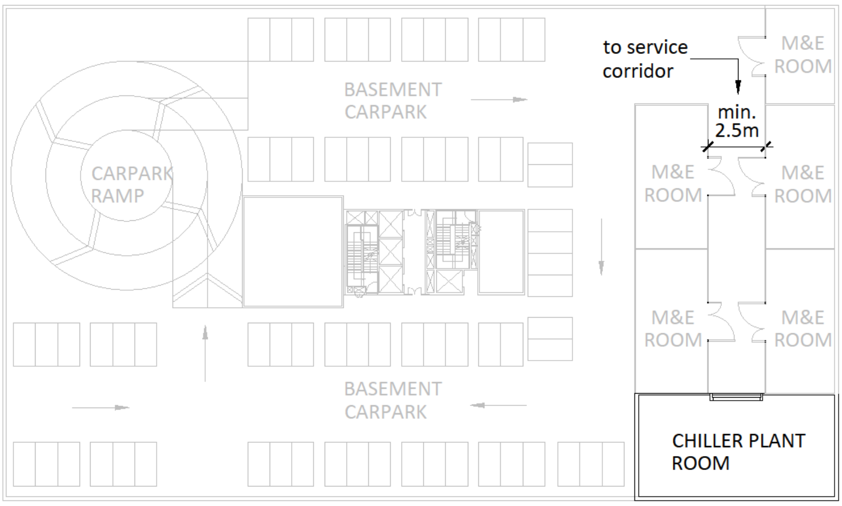

Figure 25: Basement chiller plant with service corridor

Documentation requirements

Design Stage

- ACMV plan drawing/chiller plant detailing drawing showing the operable openings and direct access from the driveway to the chiller plant room.
- Architecture/mechanical floor plan showing the service corridor width.
- Tender specifications showing the requirement on equipment delivery and replacement plan submission for approval by contractor.

Verification Stage

- Shop drawings/as-built drawings indicating the access provisions and illustration on future equipment replacement.
- Equipment replacement plan illustrating the future equipment replacement.
- Photographs indicating access provisions

Design strategy and assessment: (prerequisite)

b. Where chiller plant is located on the rooftop/service floor

i) Provide operable opening and adequate hoisting space.

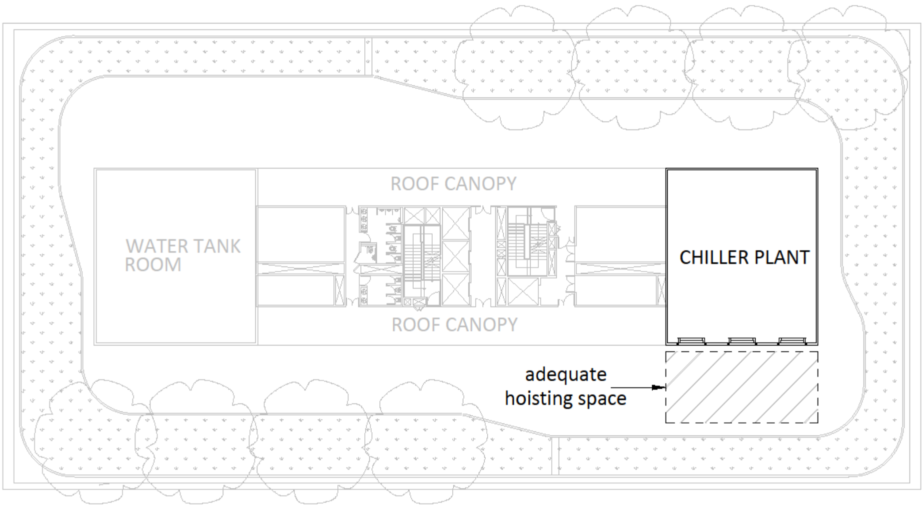

Figure 26: Rooftop chiller plant with operable opening and adequate hoisting space

Documentation requirements

Design Stage

- Tender drawings or specifications stating that the structure loading required for delivery and hoisting is catered.
- Tender specifications indicating the requirement for submission of chiller plant replacement plan for approval by contractor.

Verification Stage

- Equipment replacement plan with mark up on the shop drawings/as-built drawings showing the delivery route, operable opening, and space for deploying the crane and hoisting space based on actual equipment selection and roof services coordination.
- Photographs of access provision and operable openings.

3.1.2 Access to equipment requiring frequent maintenance (3 points)

Intent

To improve maintainability of the equipment and labour efficiency. To avoid safety hazard without proper access.

Design strategy and assessment: (1 point)

Davit arm provision at the top of cooling tower for repair and replacement of heavy components i.e. motor, fans etc.

a. **Provide permanent sleeve to mount davit arm for all cooling towers and hand over of 1 davit arm for each cooling tower model to building owner**

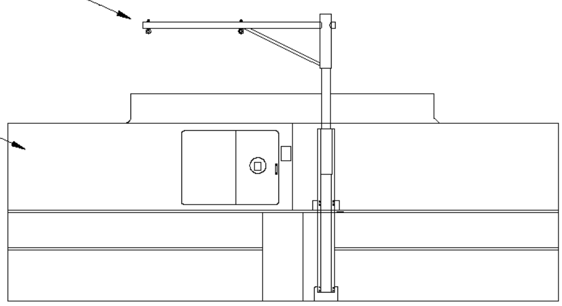

Figure 27: davit arm at top of cooling tower

Life cycle cost analysis: baseline vs design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
100% (No provision for baseline)	95%-100%	45%-50%	5-6

Baseline design strategy: no provision of motor davit at fan side
Proposed design strategy: provision of motor davit at fan side
Study period: 15 years
Yearly labour saving: 80%-90%

Documentation requirements

Design Stage

- Tender specifications showing a permanent sleeve to mount davit arm for all cooling towers
- Tender specifications on handover of 1 davit arm for each cooling tower model to building owner

Verification Stage

- As-built cooling tower detail drawing or photographs showing the permanent sleeve to mount davit arm.
- Handover documents for 1 davit arm for each cooling tower model to building owner.

Design strategy and assessment: (0.5 point)

b. **Provide cat ladder with metal enclosure (cage) to access top of the equipment i.e. cooling tower.**

Documentation requirements

Design Stage

- Tender specifications showing the requirement on cat ladder with metal enclosure.

Verification Stage

- As-built drawings/shop drawings showing the cat ladder with metal enclosure.
- Photographs showing the actual provision of cat ladder access.

Design strategy and assessment: (0.5 point)

c. **Provide metal step-over platform at the main access leading to the plant rooms to avoid stepping on rooftop services (i.e. major ductwork, pipes above 100 mm diameter, trunking exceeding 200 mm in width etc.).** The stepover platform must have minimum width of 600 mm with both sides protected by a handrail with a vertical height of at least 1 m.

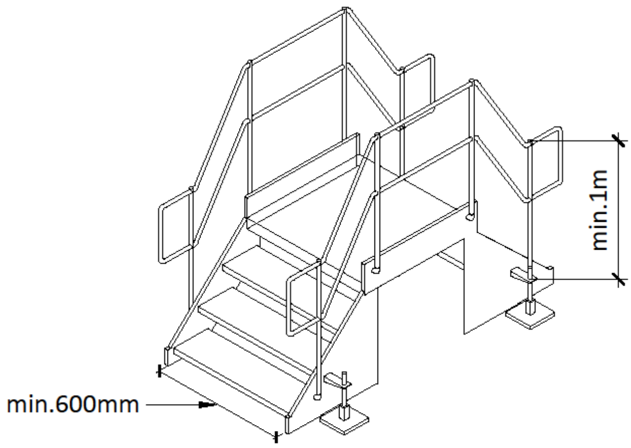

Figure 28: Step-over

Documentation requirements

Design Stage

- Tender specifications showing the requirement for metal step-over platform.

Verification Stage

- ACMV shop drawing/as-built drawing indicating the provision for metal step-over platform.
- Photographs showing the provision of metal step-over platform.

Design strategy and assessment: (1 point)

d. **Provide minimum 1.2 m wide clear access route from the nearest lift lobby or staircase to the M&E plant rooms for regular maintenance (i.e. pump room, chiller plant room including cooling tower etc.).**
The access/egress route must be sufficient in terms of space provision and loading capacity to allow safe movement of maintenance staff, the handling of major plant items, and the use of mechanical lifting devices where necessary[26].

Note: Designers should follow manufacturer's specified requirement or specialist's recommendation if the minimum access space is greater than the above stated access requirements.

Documentation requirements

Design Stage

- ACMV tender drawing/specifications capturing the access path requirement.

Verification Stage

- As-built service drawings/shop drawings indicating the access route provision from roof entrance to the M&E plantroom/equipment.
- Photographs showing the access route provision.

3.1.3 Reduce risk of corrosion and dust invasion in cooling tower (up to 1.5 points)

Intent

To improve cooling tower maintainability and avoid corrosion and dust invasion.

Note: Points can be scored for either 3.1.3b or 3.1.3c. Points will be apportioned for projects having both cross flow and counter flow cooling towers.

Design strategy and assessment: (1 point)

a. **All components in contact with condenser water or air stream must be corrosion-protected. The construction material must be either:**
   i) FRP (fiberglass reinforced polyester with UV inhibitors).
   ii) 304 stainless steel.
   iii) For galvanized steel cooling tower, the zinc coating must comply with the following:
   - **Hot-dip galvanized steel must comply with ASTM A123 (OR) G235 (OR) JIS H 8641 coating standards.**
   - **Continuous steel sheet must comply with ASTM A653 zinc coating thickness.**

Note: General requirement – applicable to both cross and counter flow cooling tower.

Components in contact with condenser water or air stream include cold water basin, hot water basin (for cross flow cooling tower) and structural framework.

Documentation requirements

Design Stage

- Tender specifications capturing the cooling tower construction material requirements (including support structures frames and accessories).

[26] Defense Works Functional Standard, Design and Maintenance Guide 08, Space requirement for plant access, operation and maintenance

Verification Stage

- Cooling tower technical data sheet/as-built drawing/factory certificates, and any relevant third-party certificate on the material properties and coatings.

Design strategy and assessment: (0.5 point)

b. For cross flow cooling tower, provide basin cover to mitigate dust invasion and algae growth in the upper water basin.

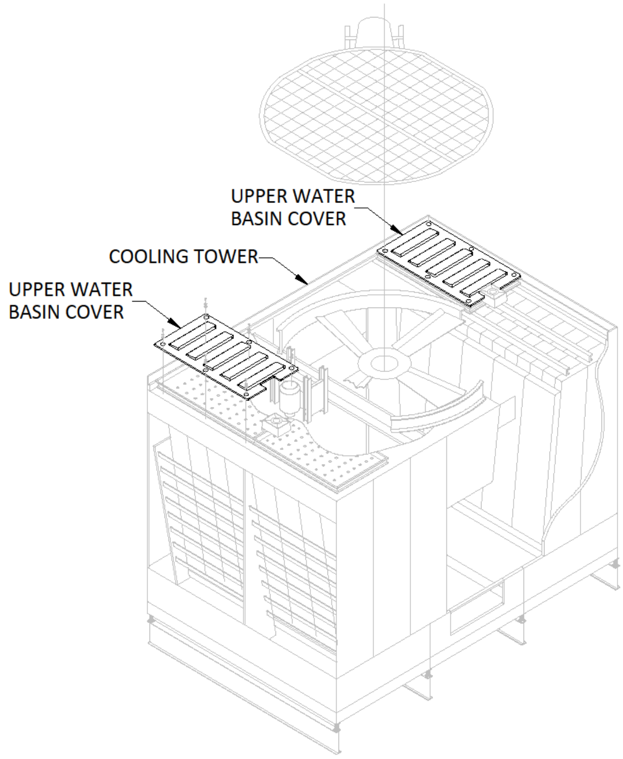

Figure 29: Cross flow cooling tower with upper water basin cover

Life cycle cost analysis: baseline vs design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
100% (No provision for baseline)	65%-70%	35%-40%	4-5

Baseline design strategy: no provision of cooling tower upper basin cover
Proposed design strategy: provision of cooling tower upper basin cover
Study period: 15 years
Yearly labour saving: 60%-70% man-hour

Documentation requirements

Design Stage

- Tender specifications capturing the requirement for additional cover for cooling tower upper water basin.
- ACMV tender drawing showing the details on cooling tower upper water basin with cover.

Verification Stage

- Shop/as-built drawing showing the cover for upper water basin. Submit relevant technical data sheet from the suppliers highlighting the cover arrangement.
- Photographs showing the provision of upper water basin cover.

Design strategy and assessment: (0.5 point)

c. **For counter flow cooling tower, provide air intake louvres to avoid sun light from entering the cooling tower basin and thus reducing algae formation.**

Note: the air intake louvres must avoid direct sunlight penetration to the cooling tower water basin. The length, depth, and angle of the louvre is subject to supplier's recommendation.

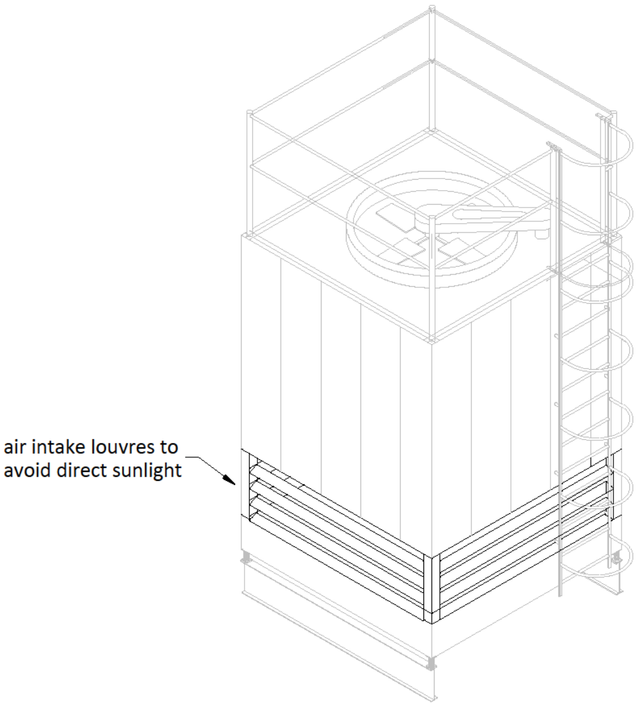

Figure 30: Counter flow cooling tower with air intake louvres

Documentation requirements

Design Stage

- Tender specifications showing the requirement of air intake louvres for cooling tower.

Verification Stage

- Catalogues/technical data sheet showing the details of air intake louvres or supplier's letter showing that the intake louvers will prevent sunlight penetration.
- Photographs of the louvres showing the implementation.

3.1.4 Reduce risk of oil/grease deposit on the cooling tower fins (1 point)

Intent

Enhance maintainability by preventing the grease deposit on the cooling tower fins.

Design strategy and assessment: (prerequisite)

a. **The kitchen exhaust outlet must be at least 5 m away from cooling tower air intake.**
   (AND)
   The kitchen exhaust must be directed either perpendicular or opposite to the cooling tower air intake.

   Note: Projects deviating from the above requirement must adopt performance driven approach (such as using CFD) to prove that kitchen exhaust is not directed towards the cooling towers.

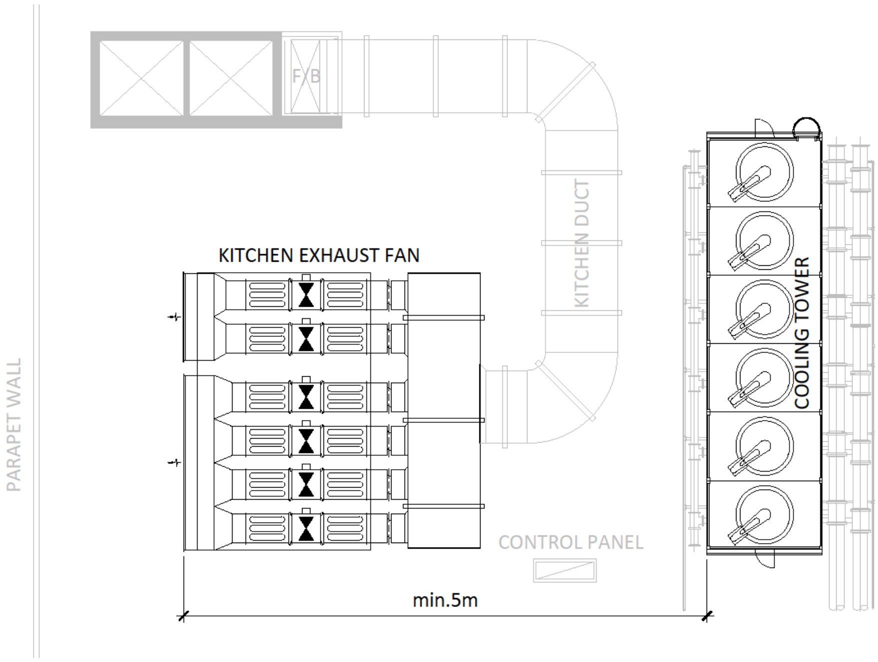

Figure 31: Roof with cooling tower and kitchen exhaust fan

Documentation requirements

Design stage

- Tender specifications highlighting the requirement for kitchen exhaust termination.
- ACMV plan drawing showing the kitchen exhaust duct termination and distance from cooling tower.

Verification Stage

- Shop drawing/as-built drawings showing the direction of kitchen exhaust discharge and distance to the cooling tower intake.
- Photographs of actual installation showing the compliance.

Design strategy and assessment: (1 point)

b. **Provide kitchen air cleaning system (i.e. air scrubber, electrostatic precipitator filters etc.) to avoid grease deposit on the cooling towers.**

Documentation requirements

Design stage

- Tender specifications capturing the kitchen air cleaning system requirement.
- ACMV tender drawings showing the requirement of the kitchen exhaust air cleaning system.

Verification Stage

- Shop drawing/as-built drawing/detail drawing showing the kitchen exhaust air cleaning system.
- Catalogue or technical data sheet showing the details of kitchen air cleaning system.

3.1.5 Reduce risk of fouling issue and improve condenser water quality (2.5 points)

Intent

Enhance maintainability and performance of the cooling towers and chillers.

Design strategy and assessment: (1.5 points)

a. **Provide microprocessor based, automatic water quality monitoring and control system linked to Building Management System (BMS).**
The critical parameters must be monitored by BMS. Auto monitoring and control is applicable to both chemical-based and non-chemical based/chemical-free water treatment system.
The critical parameters include the following:
i) Conductivity
ii) Temperature
iii) pH value
iv) Total dissolved solids (TDS)
v) Hardness
vi) Salinity
vii) Oxidation reduction potential (ORP)

Life cycle cost analysis: baseline vs design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
2X	45%-50%	25%-30%	2-3

Baseline design strategy: conventional chemical water treatment
Proposed design strategy: real-time monitoring and auto-dosing according to the water quality for chemical water treatment
Study period: 10 years
Yearly labour saving: 50-60% man-hour

Documentation requirements

Design stage

- Tender specifications showing the requirement for cooling tower water treatment with automatic monitoring and control system.

Verification Stage

- Technical data sheet/cut sheet showing the parameters monitored for water treatment system.
- BMS I/O point schedule highlighting the points monitored/controlled for water treatment system.
- Photographs of actual installation showing the compliance.

Design strategy and assessment: (1 point)

b. Provide auto-tube cleaning for water cooled chillers.

Life cycle cost analysis: baseline vs design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
100% (No provision for baseline)	85%-90%	15%-20%	3-4

Baseline design strategy: no provision of auto-tube cleaning system
Proposed design strategy: provision of auto-tube cleaning system (Ball type)
Study period: 5 years
Yearly labour saving: 30%-40% man-hour

Documentation requirements

Design stage

- Tender specifications showing the requirement for auto tube cleaning system.
- ACMV schematic drawing showing the provision of auto-tube cleaning system.

Verification Stage

- Technical data sheet/catalogue of auto tube cleaning system.
- Shop drawing/as-built chiller plant drawing highlighting the integration of auto-tube cleaning system.

3.1.6 Reduce risk of dust and debris settlement inside the cooling tower basin (up to 1.5 points)

Intent

To enhance the maintainability of the cooling towers and overall performance of the chiller plant.

Note: Project can score either for 3.1.6.a or 3.1.6.b. Total scores for 3.1.6 is capped at 1.5 points.

Design strategy and assessment: (1.5 points)

a. Provide basin sweeper system (including side stream separator) to remove coarse to fine particles and silt deposit in the cooling tower basin.

Note: The basin sweeper system must be provided for each cooling tower.

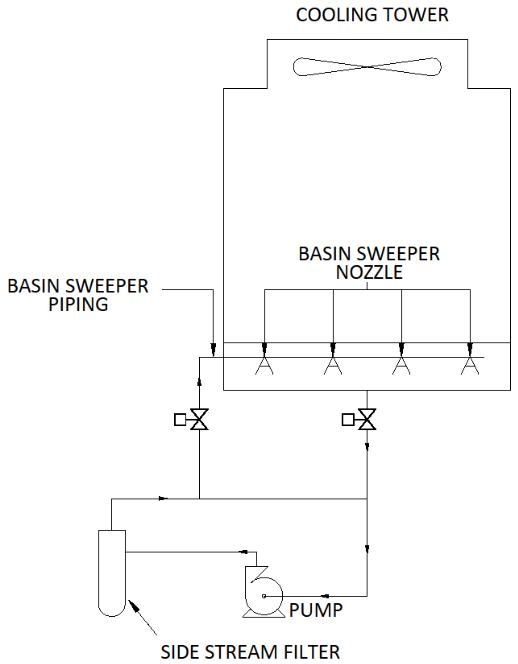

Figure 32: Cooling tower basin sweeper system

Documentation requirements

Design Stage

- Tender specifications showing the requirement on basin sweeper system and side stream separator.
- ACMV tender schematic drawings showing the details of basin sweeper and side stream separator system.

Verification Stage

- As-built drawings/shop drawings showing the adoption of basin sweeper system.
- Photographs showing the provision of basin sweeper system and side stream separator.

Design strategy and assessment: (1 point)

b. Provide side stream centrifugal separator or equivalent in condenser water loop to mitigate debris and dust accumulation.

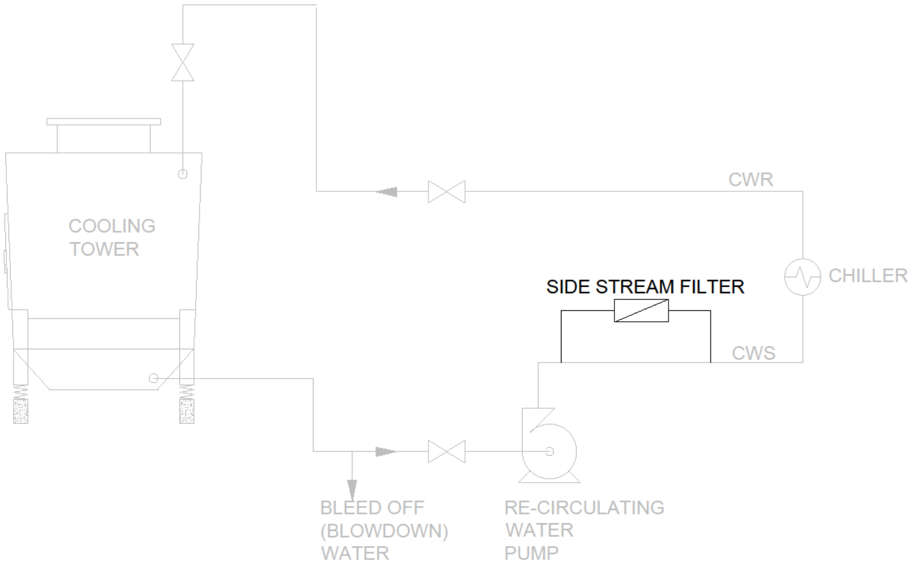

Figure 33: Schematic diagram for side stream filtration system

Life cycle cost analysis: baseline vs design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
100% (No provision for baseline)	80%-85%	40%-45%	5-6

Baseline design strategy: no provision of filtration system for cooling towers
Proposed design strategy: provision of side stream filtration system for cooling towers
Study period: 15 years
Yearly labour saving: 20%-30% man-hour

Documentation requirements

Design Stage

- Tender specifications showing the requirement on side stream centrifugal separator system.
- ACMV tender schematic drawing showing the details of side stream filtration system.

Verification Stage

- As-built drawings showing the adoption of side stream filtration system.
- Photographs showing the provision of side stream filtration system.

3.2 UNITARY AIR CONDITIONING SYSTEM – VARIABLE REFRIGERANT FLOW (VRF) (1 point)

3.2.1 Access to VRF outdoor units (prerequisite)

Intent

Provide adequate access space for VRF maintenance.

Design strategy and assessment: (prerequisite)

a. For single VRF outdoor unit installation:

Top Discharge:

i) Provide minimum 500 mm to the front for refrigerant piping and maintenance access.

ii) Provide minimum 300 mm to the suction side for air intake.

Note: The above-mentioned access requirements is based on:

- *Front/side: Wall equal to the height of the condenser unit (CU).*
- *Back: Wall Up to 500mm from the unit bottom.*

Side Discharge:

i) The outdoor units must not be stacked.

ii) Provide minimum 500 mm to the front for maintenance access.

iii) Provide minimum 150 mm to the suction side for air intake.

iv) Provide minimum 350mm on the side with refrigerant piping for maintenance

Note: The above-mentioned access requirements is based on obstacle on both suction and discharge side. For outdoor units which are obstructed by walls on multiple sides, follow manufacturer specified access provisions.

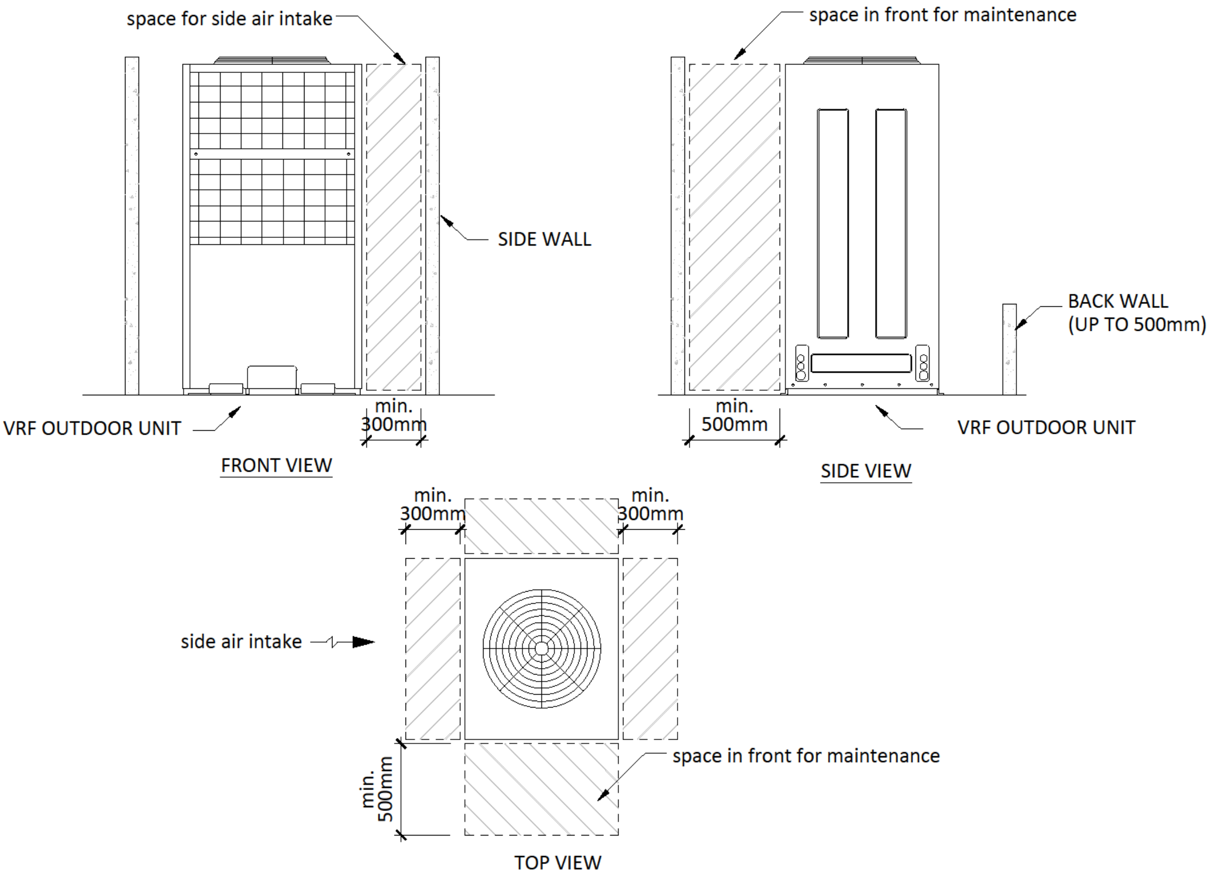

Figure 34: Space requirement for single VRF outdoor installation (top discharge)

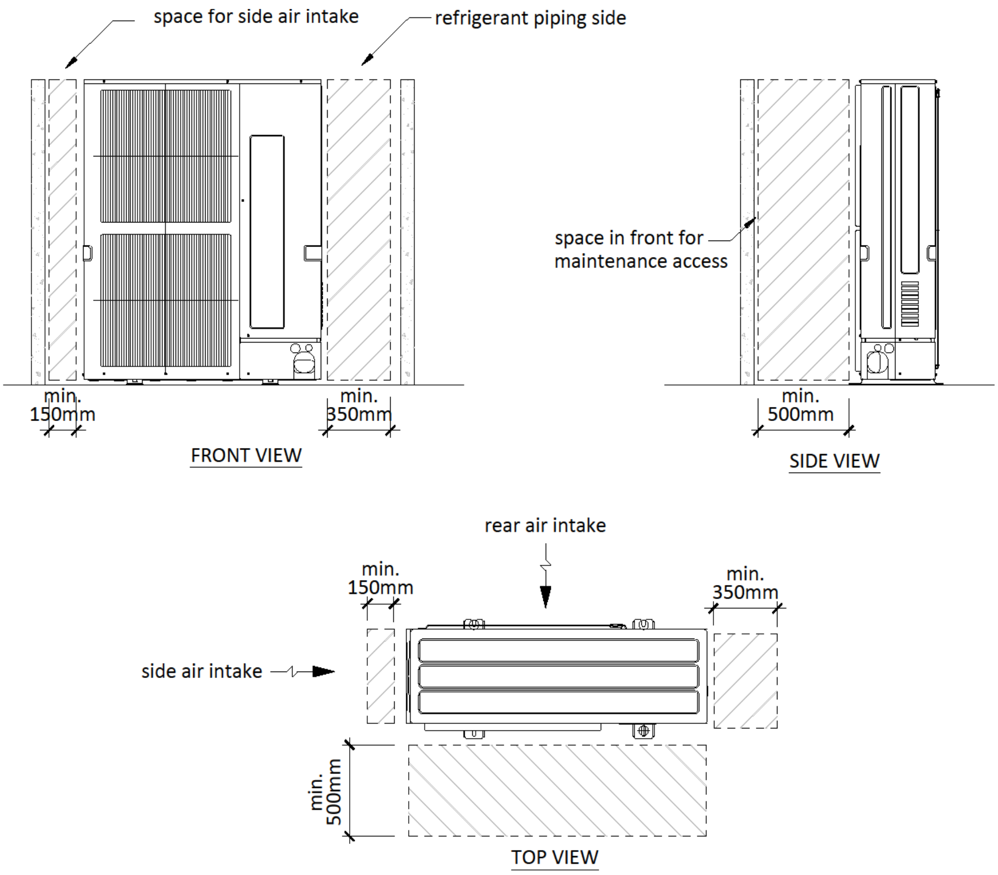

Figure 35: Space requirement for single VRF outdoor installation (side discharge)

Documentation requirements

Design Stage

- Tender specifications indicating the exact access requirement.

Verification Stage

- Shop drawing/as-built VRF layout and sectional drawings indicating the access provisions as per the actual equipment selection.
- Photographs of actual installation and access requirement.

Design strategy and assessment: (prerequisite)

b. For collective VRF outdoor unit installation:

Top Discharge:

i) Provide minimum 500 mm to the front for refrigerant piping and maintenance access.

ii) Provide minimum 300 mm to the suction side for air intake.

iii) If there is a wall at both front and back of the unit, provide minimum 1 m access space for each unit.

Note: For outdoor units which are obstructed by walls on multiple sides, follow manufacturer specified access provisions.

Side Discharge:

i) The outdoor units must not be stacked.

ii) Provide minimum 500 mm to the front for maintenance access.

iii) Provide minimum 300 mm to the suction side for air intake.

iv) Provide minimum 350mm on the side with refrigerant piping for maintenance If there is a wall on both sides, provide minimum 1 m clear access space for at least one side of the unit.

Note: For outdoor units which are obstructed by walls on multiple sides, follow manufacturer specified access provisions.

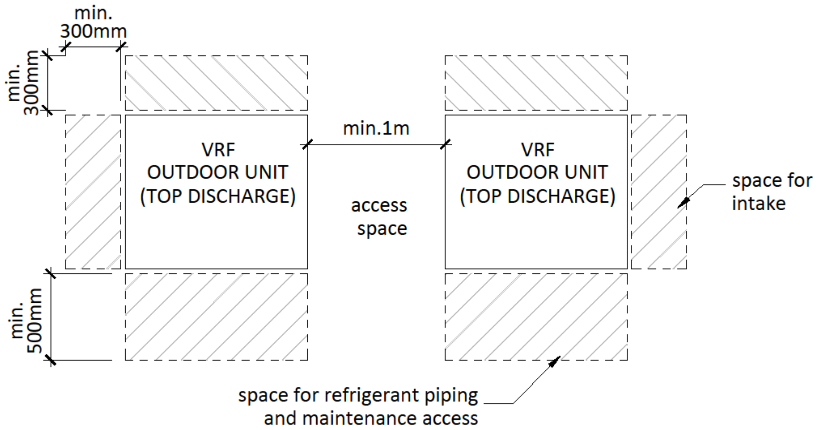

Figure 36: Space requirement for collective VRF outdoor unit (top discharge) – top view

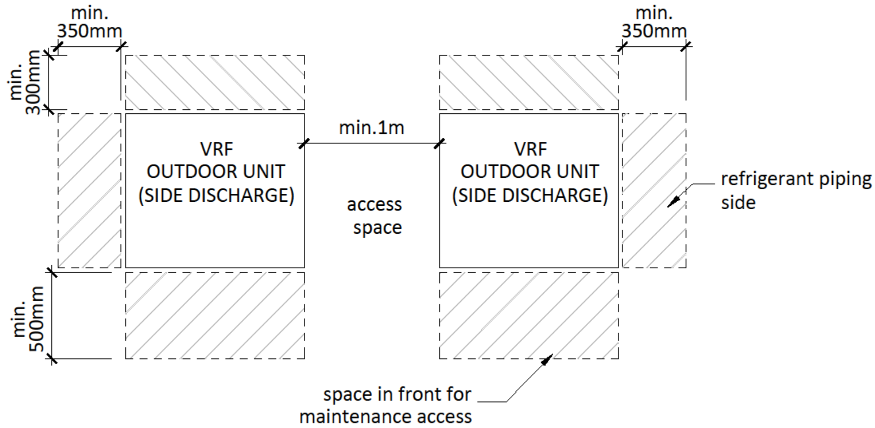

Figure 37: Space requirement for collective VRF outdoor unit (side discharge) - top view

Documentation requirements

Design Stage

- Tender specifications indicating the exact access requirement.

Verification Stage

- Shop drawing/as-built VRF layout and sectional drawings indicating the access provisions as per the actual equipment selection.

Design strategy and assessment: (prerequisite)

c. **For floor-by-floor VRF outdoor unit installation:**

Top Discharge:

i) **Provide minimum 500 mm to the front for refrigerant piping and maintenance access.**

ii) **Provide minimum 300 mm to the suction side for air intake.**

iii) **Avoid air short-circuiting, connect the air outlet via ducting to the outside wherever required.**

iv) **If the duct is terminated against the louvre, the louvre angle should be ≤20° from horizontal. The free opening for louvre screen should be minimum 70 %.**

Side Discharge:

i) **The outdoor units must not be stacked.**

ii) **Provide minimum 500mm to the front for maintenance access.**

iii) **Provide minimum 300 mm to the suction side for air intake.**

iv) **Provide minimum 350mm on the side with refrigerant piping for maintenance.**

Note: The above-mentioned access requirements is specific to outdoor units located at the service corridor facing the building exterior. For any other site-specific space constraints, refer to manufacturer's recommendations for access space requirements.

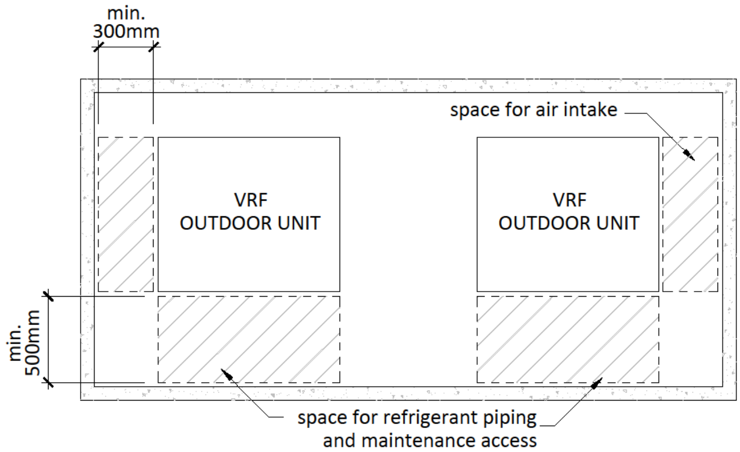

Figure 38 - Space requirement for VRF outdoor installation (top discharge) – top view

Documentation requirements

Design Stage

- Tender specifications indicating the access requirement.

Verification Stage

- Shop drawing/as-built drawing (including plan and sectional drawing) indicating the access provisions as per the actual equipment selection.

3.2.2 Avoid damage to the refrigerant pipe and insulation (1 point)

Intent

To avoid damage to refrigerant pipe with proper installation.

Design strategy and assessment: (1 point)

a. **Refrigerant pipe mounted outdoor (e.g. at roof level) must be mounted on inside raised trunking to avoid water ingress and damage to stepping/lateral impact.**

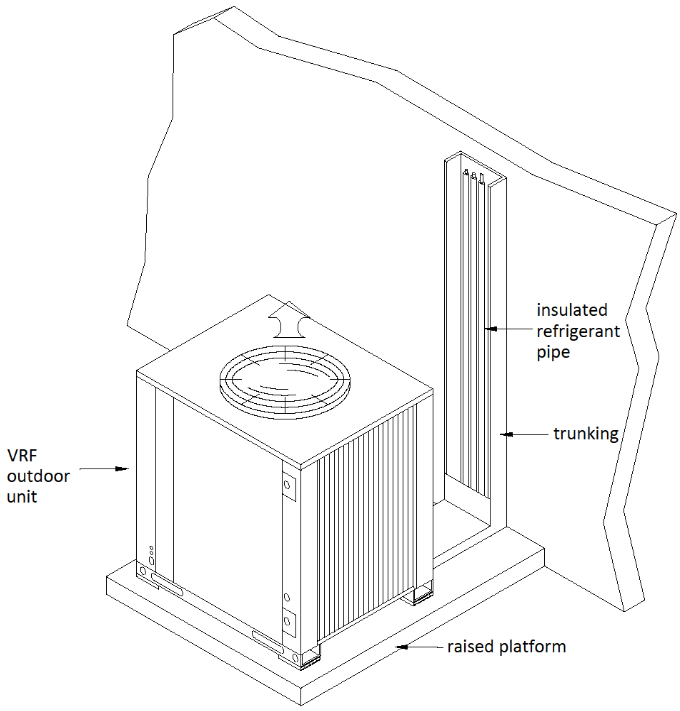

Figure 39: Trucking for refrigerant pipe

Documentation requirements

Design Stage

- Tender specification showing the requirement for raised platform with trunking.

Verification Stage

- Shop drawing/as-built VRF drawing showing the compliance for installation details.
- Photographs showing the installation.

Worked Example 6:

A mid-rise office building has been designed with two type of cooling system- chiller plant and Variable Refrigerant Flow (VRF) system. The total operating peak cooling load for chiller plant and VRF system is 4000kW and 1000kW, respectively.

- Proportion of cooling load of Chiller Plant system $= \frac{4000}{4000+1000} = 80\%$
- Proportion of cooling load of VRF system $= \frac{1000}{4000+1000} = 20\%$

3.1 Chiller Plant

Scoring for chiller plant system is shown in table below. Total points scored for this building under Chiller Plant is 9 points.

	Points	Assessment category	Used in project	Points Scored
3.1.2 Access to equipment requiring frequent maintenance	3	-	√	3
3.1.3 Reduce risk of corrosion and dust invasion in cooling tower	1.5	-	√	1
3.1.4 Reduce risk of oil/grease deposit on the cooling tower fins	1	-	√	1
3.1.5 Reduce risk of fouling issue and improve condenser water quality	2.5	-	√	2.5
3.1.6 Reduce risk of dust and debris settlement inside the cooling tower basin	1.5	-	√	1.5

3.2 UNITARY AIR CONDITIONING SYSTEM – VARIABLE REFRIGERANT FLOW (VRF)

Scoring for VRF system is shown in table below. Total points scored for this building under VRF is 1 point.

	Points	Assessment category	Used in project	Points Scored
3.2.2 Avoid damage to the refrigerant pipe and insulation	1	-	√	1

The total score after apportioning $= \mathbf{80\%} \times \mathbf{9} + \mathbf{20\%} \times \mathbf{1} = \mathbf{7.4}$ points

Note:
Apportionment of points will only apply if the building is served by both chiller plant and VRF systems. And the cooing capacity of each cooling system must not be less than 15% of cooling load otherwise apportionment would not apply as shown in worked example 8.

Worked Example 8:

A mid-rise office building has been designed with two type of cooling system- chiller plant and Variable Refrigerant Flow (VRF) system. The total operating peak cooling load for chiller plant and VRF system is 4000kW and 500kW, respectively.

Proportion of cooling load of VRF system $= \frac{500}{4000+500} = 11.1\% < 15\%$

Scoring for cooling system is the same as Worked Example 7 which is 9 points. Scoring for VRF is also 1 point.

In this scenario, 9 points will be scored for 3.1 & 3.2 as apportioning will not apply because the cooling capacity of VRF is less than 15% of the total cooling capacity.

3.3 AIR DISTRIBUTION SYSTEM (4 points)

3.3.1 Access space for maintenance of air distribution system (prerequisite)

Intent

To provide efficient and safe maintenance access around the air distribution system for regular maintenance.

Design strategy and assessment: (prerequisite)

a. Fan coil units (FCU)

i) Provide ceiling access panel with minimum 600 mm x 600 mm to access filter, cooling coil, and fan section for regular maintenance and replacement.

ii) Cooling coil pipe connection access – Provide minimum 450 mm clear space after pipe connection from any obstacle.

iii) FCU side clearance - Provide minimum 200 mm access space from any obstacle.

iv) FCU and key components such as actuator control valve, local control panel (LCP) shall be directly accessible and within maximum 600mm from the access panel.

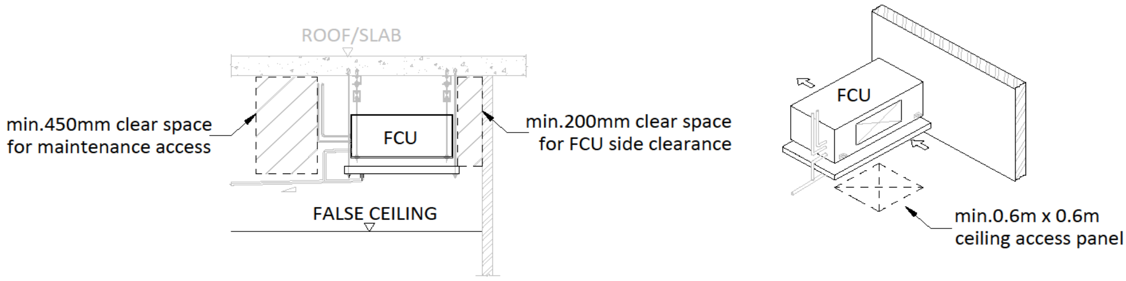

Figure 40: Typical access provision for FCU

Note: Designers should follow the manufacturer's specified space requirement if the minimum access space is greater than the above stated values. This item is not applicable to projects without fan coil units.

Documentation requirements

Design Stage

- Tender specifications indicating the access requirement.

Verification stage

- As-built drawings/shop drawings (including plan drawing/section) at appropriate scale highlighting the FCU access provision.
- Photographs showing implementation.
- O&M manual indicating the FCU maintenance strategy report.

Note: The typical detailing should match the shop drawing/as-built drawing layout.

Design strategy and assessment:

b. Access to FCU mounted at heights (i.e. atrium, lobby space)

i) Access provisions stated in 3.3.1a.

(AND) either (bii), (biii) or (biv).

ii) Provide clear access route for Mobile Elevated Work Platforms (MEWP) to reach the lobby, atrium space from the nearest door entrance.

- **Provide clear access with entrance door/ opening of 1.8 m width x 2.4 m height and working base of 1.8 m width x 2 m length if the mounting height is less than or equal to 10.5 m.**
- **Provide clear access with entrance door/ opening of 2 m width x 2.8 m height and working base of 2 m width x 2 m length if the mounting height is greater than 10.5 m.**

Clear and unobstructed access shall be provided from the entrance to the location directly below the FCUs. This shall include the height and width of entrance door, the clearance along the MEWP access path as well as the working base for MEWP to carry out the maintenance work. The floor (loading and finishes) shall be able to withstand the MEWP to be deployed for maintenance work. The deployment and operation of MEWP shall comply with authority requirements. The actual clear access shall depend on the proposed type of MEWP to be used and the manufacturer's recommended clearances through the access way.

iii) **Provide alternative access (e.g. maintenance platform, access from top floors etc.) without having to access from the atrium floor.**

iv) Locate FCU less than 3 m from FFL for easy access and maintenance.

Note: This item is not applicable to projects without fan coil units mounted at heights.

Documentation requirements:

Design Stage

- Plan drawing(s) showing the access route for MEWP movement to the atrium/lobby space.
- ACMV plan drawing/section at appropriate scale showing the alternative access provisions (OR) tender specifications indicating the access provisions (i.e. maintenance platform etc.).
- Tender specifications indicating the access requirement.

Verification Stage

- As-built drawings/shop drawings with actual access route marking from building entrance to the atrium/lobby space.
- As-built drawings/shop drawings (including plan drawing/section) showing the alternative access provisions (i.e. maintenance platform, access from mezzanine floor etc.).
- As-built drawings/shop drawings (including plan drawing/section) indicating the mounting height ≤ 3 m.
- Photographs showing implementation.

3.3.2 Reduce risk of water ponding and algae growth in the AHU room (0.5 point)

Intent

Improve maintainability by providing proper termination of the AHU drain pipe and adequate floor treatment.

Design strategy and assessment: (prerequisite)

a. **AHU drain pipe must be terminated directly above the floor trap to avoid any water spillage.**

Note: The drain pipe must have minimum 1:100 slope to avoid any water choke. This item is not applicable to projects without AHUs.

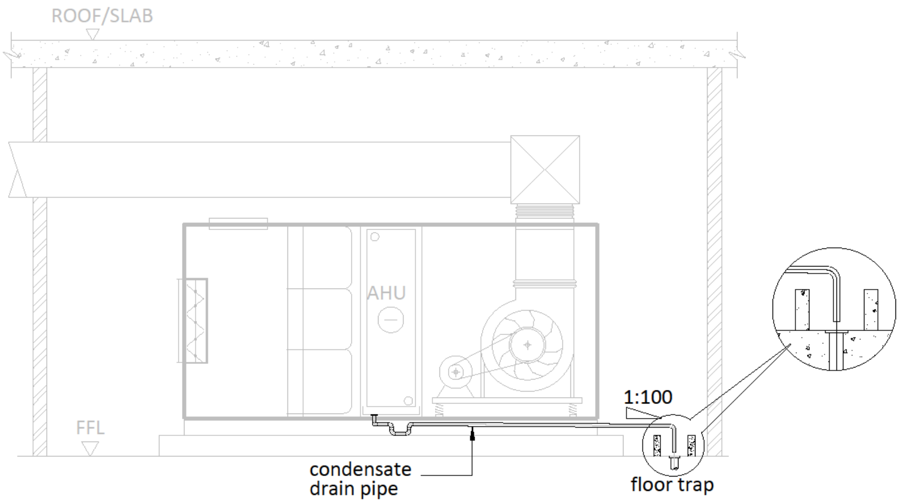

Figure 41: Typical AHU condensate drain termination

Documentation requirements:

Design Stage

- ACMV plan /section / typical detail drawings at appropriate scale showing the typical drain termination and slope requirement.
- Tender specifications indicating the AHU condensate drain pipe must be at least 1:100 gradient and terminated directly above the floor trap.

Verification stage

- As-built drawings/shop drawings (including plan drawing/section) showing the typical drain termination and slope requirement.
- Photographs showing implementation.

Design strategy and assessment: (0.5 point)

b. AHU room floor to be provided with epoxy coating to avoid algae and mould growth.

Note: The epoxy coating must be applied in strict accordance with the manufacturer's instructions, by an applicator trained and approved by the manufacturer. The key performance properties such as tensile strength, hardness, abrasion resistance etc. must comply with ASTM or equivalent standards. This item is not applicable to projects without AHUs or when AHUs are not located in rooms.

Documentation requirements:

Design Stage

- Tender specifications indicating the AHU room floor epoxy coating requirement.

Verification stage

- Product specifications/catalogue highlighting the epoxy coating and applicable performance properties.
- Photographs showing implementation.

3.3.3 Reduce risk of choke of condensate drain pipes (prerequisite)

Intent

Prevent choking of condensate drain pipe, thus avoiding frequent maintenance calls. To avoid operational issues to tenant and landlord ACMV equipment.

Design strategy and assessment: (prerequisite)

a. The horizontal drain pipes must have minimum slope of 1:100 for easy flow of condensate drain.
b. Provide T-joint before terminating the individual drain pipe from AHU to the main drain stack for periodic cleaning.

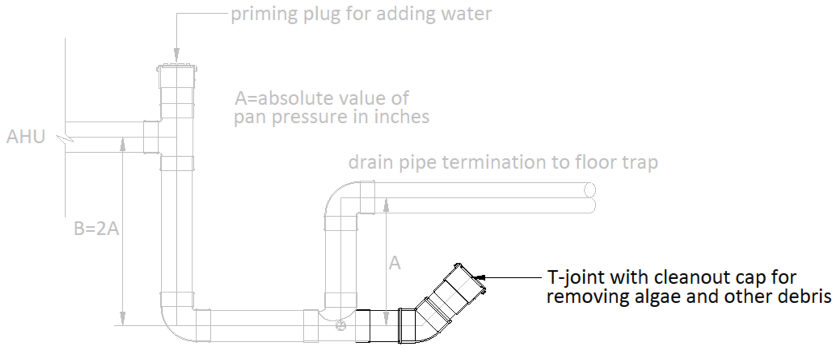

Figure 42: Typical detail for AHU drain termination

Note: This solution is only applicable when the condensate drain pipe for more than 1 AHU is connected to the same condensate stack. This will not be applicable if individual AHU discharges to floor trap.

Documentation requirements:

Design Stage

- Tender specifications indicating the condensate drain pipe slope requirement.
- ACMV typical detail drawing showing the drain termination and T-joint arrangement.

Verification stage

- As-built drawings/shop drawings showing the condensate drain pipe gradient
- Photographs showing the T-joint

3.3.4 Reduce frequency of replacement for AHU filters (1.5 points)

Intent

Prevent frequent replacement of filters and achieve operational cost savings.

Design strategy and assessment: (1.5 points)

a. **Provide differential pressure switch linked to BMS for real-time monitoring of the filter choke status. (Prerequisite)**
Note: Differential pressure switch must be provided for both primary and secondary filter for PAHUs and AHUs. Items a to c will not be applicable to projects without AHUs.

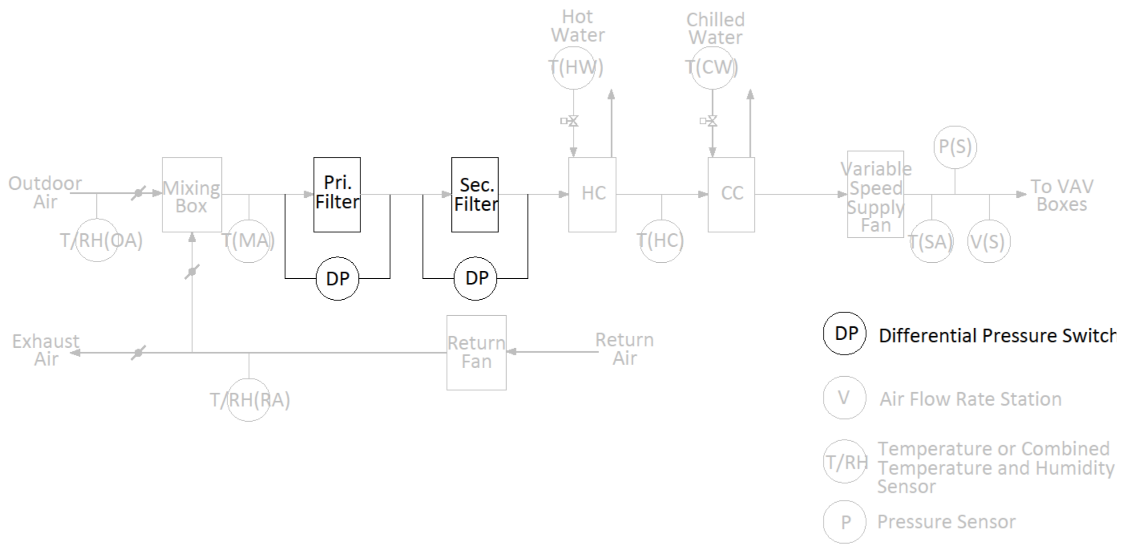

Figure 43: AHU diagram showing the differential pressure switch

b. **Specify fibre glass filter media with average initial resistance not greater than 90 Pa for primary filter (MERV 8 and ISO ePM10 50%) and 145 Pa (MERV 14 and ISO ePM1 80%) for secondary filter. (0.5 Point)**
Note: Synthetic media with initial static charge is not acceptable.

c. **Specify filters with better Life Cycle Cost for increased service life and lower cost of ownership. LCC should capture the key parameters such as "Total cost of ownership, service life, Energy consumption details and Indoor Air Quality performance". (1 Point)**

Note:
i. Total cost of ownership shall be in Singapore dollars
ii. Energy consumption is based on 0.2 S$/KWH
iii. Indoor Air Quality shall be complaint to ISO 16890/ ASHRAE 52.2:2017

Life cycle cost analysis: baseline vs design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
55%-60%	60%-65%	30%-35%	1 year

Baseline design strategy: Conventional filters
Proposed design strategy: Filters with better LCC
Study period: 5 years
Yearly labour saving: 20-30% man-hour

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
3X	45%-50%	40%-45%	1 year

Baseline design strategy: AHU with periodic filter replacement
Proposed design strategy: AHU with filter replacement frequency based on pressure differential sensor
Study period: 10 years
Yearly labour saving: 20-30% man-hour

Documentation requirements:

Design Stage

- Tender specifications/ drawings indicating the filter type, initial resistance for primary and secondary filter.
- Typical filter selection with LCC computation
- Typical detail drawing/BMS point schedule showing the showing the provision of differential pressure switch.
- Tender specifications indicating the differential pressure switch requirement.

Verification stage

- Technical data sheet/ drawing showing the filter type, initial resistance for primary and secondary filter
- BMS point schedule showing the provision of differential pressure switch.
- Photographs showing the implementation.
- BMS screenshot showing the integration for real-time monitoring of the filter condition.

3.3.5 Avoid frequent re-alignment of fan parts i.e. pulley, bearings, and belts (2 points)

Intent

To avoid frequent alignment/failure of fan parts i.e. pully, bearings, and belts. To improve maintainability and reliability of the air handling unit.

Design strategy and assessment: (2 points)

a. **Specify AHU fan system with less moving parts (i.e. fans with direct drive system) for enhanced reliability and reduced downtime.**
   Note: Points will be prorated for buildings with more than 75% of cooling capacity served only by FCUs. Spaces that are served by FCUs with pre-cooled fresh air from PAUs are not considered as spaces served only by FCUs.

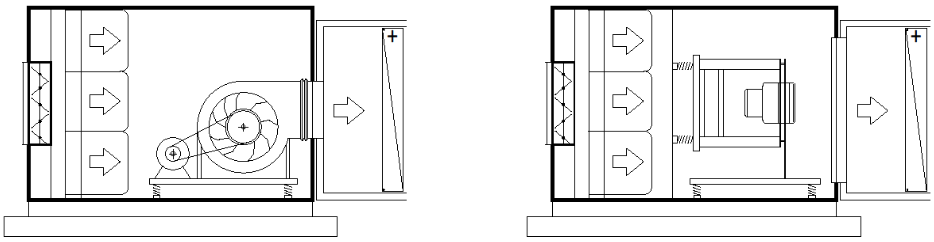

Figure 44 : Conventional (left) and Direct Drive Fan system (right)

Life cycle cost analysis: baseline vs design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
40%-45%	45%-50%	20%-25%	4-5

Baseline design strategy: AHU fans with belt driven
Design strategy: AHU fans with direct driven
Study period: 15 years
Yearly labour saving: 80%-90% man-hour

Documentation requirements:

Design Stage

- Tender specifications indicating the direct drive fans.
  Note: Applicable to all AHU's.

Verification stage

- Technical data sheet/catalogue showing the direct drive fan system which includes general arrangement (GA) drawing indicating the fan arrangement, number of fans etc.
- As-built equipment schedule indicating the direct drive fan system.
- O&M manual indicating the fan maintenance strategy report.

Worked Example 7:

A low-rise commercial building has been designed with air handling units (AHUs) serving the common areas and fan coil units (FCU) serving the retail units. Pre-cooled air from PAU is also provided to the retail units. The AHUs and PAU have direct drive fans.

<u>Equipment capacity</u>

Air Handling Units (AHUs)	200 kW
Pre-cooled Air Handling Unit (PAU)	150 kW
Fan Coil Units (FCUs)	550 kW

As the retail units are served by both FCUs and pre-cooled air from PAUs, they are not classified as spaces only served by FCUs.

In this case, the project will score **2 points** as direct drive fans are provided for the AHUs and PAU.

Worked Example 8:

A low-rise commercial building has been designed with air handling units (AHUs) serving the common areas and fan coil units (FCU) serving the retail units. Pre-cooled air is not provided to the retail units. The AHUs have direct drive fans.

Equipment capacity

Air Handling Units (AHUs)	200 kW
Fan Coil Units (FCUs)	700 kW

Proportion of cooling capacity served only by FCUs $= \frac{700}{700+200} = 77.8\%$

In this case, this item will be not applicable (NA) and the points would be prorated as the proportion exceeds 75%.

3.4 DOMESTIC WATER SUPPLY (1 point)

3.4.1 Access space for maintenance of water tank (prerequisite)

Intent

To provide adequate space for the safe and efficient maintenance of the water tank.

Design strategy and assessment: (prerequisite)

a. **Provide minimum clear width of 1.2 m access walkway to water tank from the nearest staircase or lift.**

Documentation requirements

Design Stage

- Plumbing drawing/C&S drawing/specifications capturing the access space requirements.

Verification Stage

- Shop/as-built drawing indicting the actual access space provisions.
- Photographs showing the space provision.

3.5 SANITARY SYSTEM (2 points)

3.5.1 Access provision to sanitary pipes and design detailing for ease of maintenance (1 point)

Intent

Good design practices that minimize the chance of choked sanitary pipe.

Design strategy and assessment: (1 point)

a. **Specify hubless elbows for sanitary stacks with horizontal transfers.**

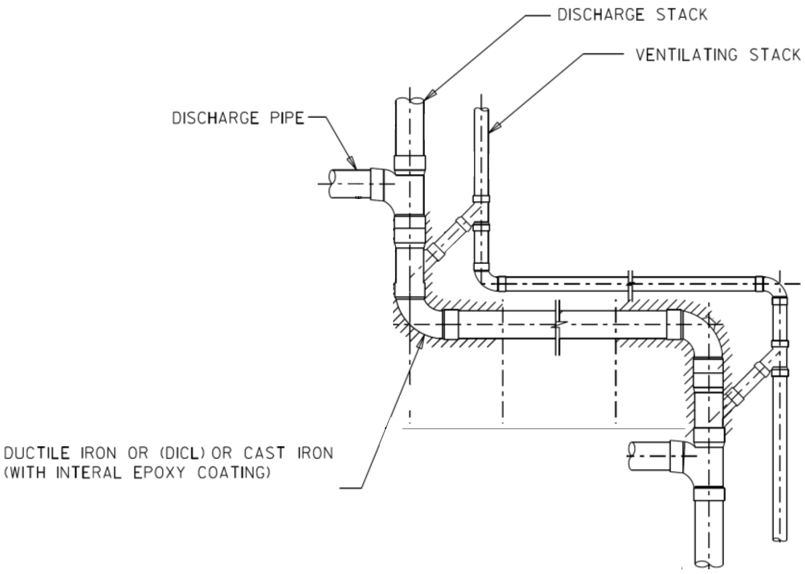

Figure 45: Hubless elbows for sanitary stacks with horizontal transfers[27]

Documentation requirements

Design Stage

- Sanitary drawings showing the details of ductile iron or cast-iron elbows that are used for UPVC sanitary stacks with transfers.

Verification Stage

- As-built sanitary drawings showing the details of ductile iron or cast-iron elbows that are used for UPVC sanitary stacks with transfers.

3.5.2 Reduce risk of chokes in the sanitary pipe (1 point)

Intent

To prevent chokes in the sanitary pipe.

[27] Code of Practice on Sewage and Sanitary Works, 2019

Design strategy and assessment: (prerequisite)

a. For buildings with food and beverage (F&B) units, the AHU condensate drain must not be linked to kitchen waste discharge pipes.

Documentation requirements

Design Stage

- Sanitary tender drawings/specifications showing AHU condensate drain requirements.

Verification Stage

- Sanitary shop/as-built drawings showing the AHU condensate drain requirements.

Design strategy and assessment: (1 point)

b. Provide at least 75% of the risers with continuous vertical run without any offsets to reduce the additional bends/joints.

Note: Above requirement is applicable only to all typical floors in building.

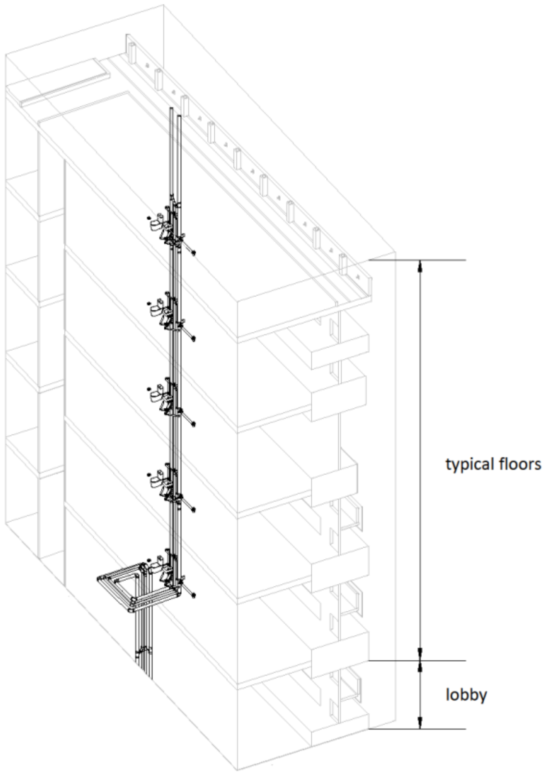

Figure 46: Risers with continuous vertical run without any offsets for typical floors

Documentation requirements

Design Stage

- Sanitary tender drawings/specifications capturing the vertical runs requirements.

Verification Stage

- Sanitary shop/as-built drawings showing the vertical risers and offsets.
- Calculations showing the % of risers without any offsets.

3.6 Fire Protection System (2 points)

3.6.1 Prevent the lack of flexibility for maintenance and testing of sprinkler system (1 point)

Intent

To ease the maintenance and general testing of fire sprinkler system.

Design strategy and assessment: (prerequisite)

a. Locate the flow switch drain valve in rooms with floor trap (i.e. toilet, AHU room etc.).

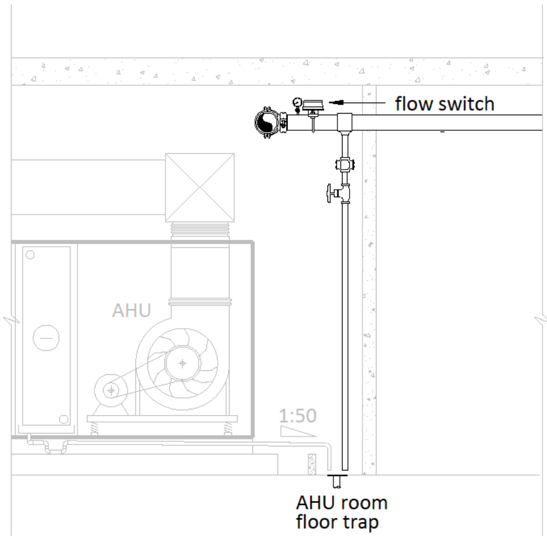

Figure 47: Flow switch drain valve in rooms with floor trap

Note: Items a and b will not be applicable to projects without sprinkle system.

Documentation requirements

Design Stage

- Fire protection system tender drawing/specifications showing the flow switch drain valve in rooms with floor trap.

Verification Stage

- Fire protection system as-built drawing showing the drainage arrangement.
- Photographs showing the implementation.

Design strategy and assessment: (1 point)

b. Provide smart feature such as the automatic flow switch testing system to automate the functional test for the fire sprinkler system.

Periodic inspection, testing, and maintenance of sprinkler system are essential for proper sprinkler function. A timely basis flow switch test is a requirement stipulated in CP52[28]. Conventionally during a routine test, water is discharged from the downstream end of the pipe, causing a drop in the pressure. This pressure difference across the flow switch generates a water flow causing the flow switch to operate. The conventional

[28] CP 52: 2004 Singapore Standard, Code of Practice for Automatic Fire Sprinkler System

approach is labour intensive and costly. This solution recommends a simplified and automatic flow switch testing.

Life cycle cost analysis: baseline vs design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
5X	95%-100%	60%-65%	5-6

Baseline design strategy: conventional flow switch testing system
Proposed design strategy: automatic flow switch testing system
Study period: 25 years
Yearly labour saving: 80%-90% man-hour

Documentation requirements

Design Stage

- Tech specifications showing the requirement on automatic flow switch testing system.

Verification Stage

- As-built fire sprinkler schematic drawing showing the details of automatic flow switch testing system.
- Photographs showing the implementation.

3.6.2 Reduce risk of damage and periodic replacement of fire-rated boards due to exposure to high humidity and water (1 point)

Intent

To prevent the damage and prolong the lifespan of fire-rated materials.

Design Strategy and assessment: (1 Point)

a. **Specify the use of weatherproof fire-rated materials for Fire Protection services such as wet/dry riser and hydrant pipes etc. (0.5 points)**
b. **Specify the use of weatherproof fire-rated materials for Mechanical Ventilation services such as kitchen exhaust ducts etc. (0.5 points)**

Note:

Item (a) is not applicable to projects where fire-rated materials are not used for fire protection services. Similarly, item (b) is not applicable to projects where fire-rated materials are not used for mechanical ventilation service.

This criterion applies to both indoor and outdoor fire-rated materials.

Documentation requirements

Design Stage

- Tender specifications showing the requirement on weatherproof fire-rated materials.
- Tender drawings indicating the location of weatherproof fire-rated materials

Verification Stage

- Product catalogue of weatherproof fire-rated materials
- As-built drawings indicating the location of weatherproof fire-rated materials
- Photographs of implementation
- PO/DO for the weatherproof fire-rated materials.

3.7 BUILDING MANAGEMENT SYSTEM (1 point)

3.7.1 Access space above false ceiling for maintenance of sensors and actuators (1 point)

Intent

To provide access and maintenance space for the sensors and actuators above false ceiling

Design strategy and assessment: (0.5 point for each item, up to 1 point)

a. Provide ceiling access panel with minimum opening of 600 mm x 600 mm.

Note: Access panel is used in false ceilings to access critical equipment for service, maintenance, and repairs. Provide access panel with clear 600 mm x 600 mm opening (excluding frame and structural support). The access panel can be either removable ceiling panels or large ceiling tiles, or fixed gypsum boards. The access panel must open completely with either single or double door design. Items a and b will not be applicable to projects without BMS.

b. Sensors and actuator should be located within reachable distance of 600mm from the access panel.

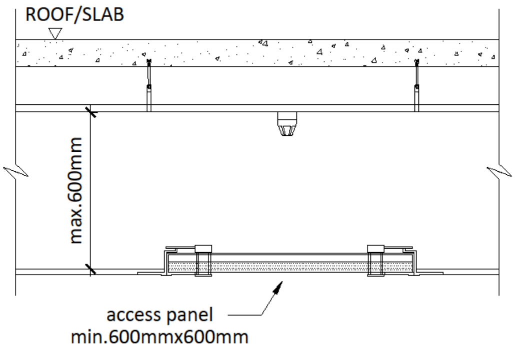

Figure 48: Access panel

Documentation requirements

Design Stage

- Tender specifications/drawings highlighting the access panel size requirement.
- Tender specifications/drawings highlighting the distance from the access panel to the sensors and actuators.

Verification Stage

- As-built drawings and photographs highlighting the provision of the access panel.
- As-built drawings and photographs highlighting the distance from the access panel to the sensors and actuators.

3.7.2 Access to control panels for regular maintenance (prerequisite)

Intent

To provide access and maintenance space for the control panels located at heights.

Design strategy and assessment: (prerequisite)

a. **The top of the control panels must be maximum 1.8 m from the finished floor level (FFL) to facilitate direct access.**
   (OR)
   The control panels located at heights must have direct access from scaffolding, ladders etc. Provide minimum 800 mm clear access space in front of the control panels.

   Note: This item will not be applicable to projects without BMS.

Documentation requirements

Design stage

- Tender specifications/drawings highlighting the control panel access requirements.

Verification Stage

- ACMV/BMS shop/as-built drawings showing the mount height of the control panel.
- ACMV/BMS shop/as-built drawing highlighting the access space provision in front of the control panel.
- Photographs showing the access provision.

4.1 LIGHTING SYSTEM (2 points)

4.1.1 Reduce frequency of light replacement (1 point)

Intent

To select more reliable light fittings for less frequent replacement.

Design strategy and assessment: (1 point)

a. **Use reliable light fixtures such as LED light (LM-80[29] B30 L70 @ L50,000) which requires less frequent replacement.**

LED life time (L value): the lifetime of LED module is defined as the time it takes until its light output, or lumen maintenance, reaches certain percentage of the initial output. L70 at 50,000 indicated 70% of the initial lumens that remains after end-of-life of 50,000 hours.
B value: The failure fraction for B_y expresses only the gradual light output degradation as a percentage y of a number of LED modules of the same type that at their rated lift designates the percentage (fraction) of failures. The value B30 indicates that the declared L-value will be achieved by minimum 70% of the LED modules and that the remaining 30% may have a lower lumen value.
LM-80 is the test standards which specified how LED manufacturer LED components to determine their performance over time.

Life cycle cost analysis: baseline vs design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
50%-55%	20%-25%	5%-10%	2-3

Baseline design strategy: not reliable lighting at height
Proposed design strategy: LED with reliable drivers at height
Study period: 5 years
Yearly labour saving: 40%-50% man-hour

Documentation requirements

Design Stage

- Drawings/lighting specifications showing the light fixture specifications.

Verification Stage

- Technical data sheet and cut-sheet showing the light fixture specifications.
  Note: Points scored for 4.1.1b can be apportioned.

[29] IESNA-LM-80: IES approved method: measuring lumen maintenance of LED light sources

Worked Example 9:

A mid-rise office building has been designed with the following light fittings. Only 5W LED downlight selected comply with 4.1.1.b requirement.

Description	Type of lighting	Number of light fittings	Compliance	Points scored after apportioning
4.1.1b - Use reliable light fixtures such as LED light (LM80 B30 L70@ L50,000) which requires less maintenance.	3W LED downlight	300	No	0.3
	5W LED downlight	300	Yes	
	10W LED downlight	400	No	

- Total number of Light Fixtures = 1000 no's
- Total number of Light Fixtures comply with the solution= 300 no's
- Proportion of Light Fixtures comply with the solution $= \frac{300}{1000} = 30\%$

Total points scores = 0.3 x 1 = 0.3 point

Therefore, the final score after apportioning for section 4.1.1.b will be 0.3 point.

4.1.2 Reduce the risk of light flickering (0.5 point)

Intent

To use reliable electronic ballast/LED control gear to prevent premature failure which lead to light flickering.

Design strategy and assessment:

a. **Specify constant DC output type LED driver complying with the following IEC standards to minimise flickering:**

   i) **IEC 62384**[30]

   Note: The standard specifies performance requirements for electronic control gear, the control gear modules specified in this standard are designed to provide constant voltage or current.

   ii) **IEC 61347 Part 1 and Part 2-13**[31]

   Note: The standard specifies general and safety requirements of LED driver which provides safety to the driver user.

b. **For non-LED light fixtures, use electronic ballast to cut off power supply to prevent flickering due to lamp failure.**

   Note: The electronic ballast will cut off power to failed fluorescent tube which prevents flickering as in the case of magnetic ballast.

Documentation requirements

Design Stage

- Tender drawings/specifications highlighting the compliance to IEC standards for LED light fittings and provisions of electronic ballast for non-LED light fittings.

Verification Stage

[30] IEC 62384, DC or AC supplied electronic control gear for LED modules – performance requirement

[31] IEC 61347-1:2015, Lamp Control Gear –Part 1: General and Safety Requirements

IEC 61347-2-13: 2014, Lamp Control Gear: Part 2-13, Particular Requirements for d.c or a.c. Supplied Control Gear for LED Modules

- Technical data sheet of LED light fittings stating the compliance to IEC standards and third-party test certificates. Technical data sheet of electronic ballast for non-LED light fittings.

Worked Example 10:

A mid-rise office building has been designed with the following light fittings. Only 5W LED downlight selected comply with 4.1.2 requirement.

Description	Type of lighting	Number of light fittings	Compliance	Points scored after apportioning
4.1.2a - Specify constant DC output type LED driver complying with the following IEC standards to minimise flickering.	3W LED downlight	300	No	0.15
	5W LED downlight	300	Yes	
	10W LED downlight	400	No	

- Total number of Light Fixtures = 1000 no's
- Total number of Light Fixtures comply with the solution= 300 no's

- Proportion of Light Fixtures comply with the solution $= \frac{300}{1000} = 30\%$

Total points scores = 0.3 x 0.5 = 0.15 point

Therefore, the final score after apportioning for section 4.1.2 will be 0.15 point.

4.1.3 Reduce the risk of LED light colour shift (0.5 point)

Intent

To use quality LED luminaire and light source to prevent LED premature failure/degrading.

Design strategy and assessment: (0.5 point)

a. **Specify LEDs tested to ANSI/IES LM-79-19 and LM-80-15 to ensure LED Performance.** [32,33]
LED light sources are required designed and certified to meet specified operating hours and the LED performance when it is used in a luminaire. Colour shift often happens when the light output deteriorates. The colour shift is recommended to be less than 2-step MacAdam Ellipses across the lift time of the LED light fixtures.

Note:

Points scored for 4.1.3 can be apportioned.

Documentation requirements

Design Stage

- Tender drawings/specifications highlighting the requirements including the test standards IESNA LM-79-19 and LM-80-15.

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[32] ANSI/IES-LM-79-19: Approved Method: Optical and Electrical Measurement of Solid-state Lighting Products
[33] ANSI/IES LM-80-15: Approved Method: Measuring luminous Flux and Color Maintenance of LED Packages, Arrays and Modules

Verification Stage

- Technical data sheet, cut-sheet and third-party test certificates indicated with the compliance with the specified standards/requirements.

Worked Example 11:

A mid-rise office building has been designed with the following light fittings. Only 3W LED downlight and 5W LED downlight selected comply with 4.1.3 requirement.

Description	Type of lighting	Number of light fittings	Compliance	Points scored after apportioning
4.1.3 - Specify LEDs tested to ANSI/IES LM-79-19 and LM-80-15 to ensure the LED performance.	3W LED downlight	300	Yes	0.3
	5W LED downlight	300	Yes	
	10W LED downlight	400	No	

- Total number of Light Fixtures = 1000 no's
- Total number of Light Fixtures comply with the solution= 600 no's

- Proportion of Light Fixtures comply with the solution $= \frac{600}{1000} = 60\%$

Total points scores = 0.6 x 0.5 = 0.3 point

Therefore, the final score after apportioning for section 4.1.3 will be 0.3 point.

4.2 POWER DISTRIBUTION (2 points)

4.2.1 Reduce risk of water Ingress into electrical room (prerequisite)

Intent

To prevent damage to electrical equipment inside the electrical room.

Design strategy and assessment: (prerequisite)

a. **Electrical room must be raised by minimum 100 mm against the outside passageway.**

Raising the switch room floor level against its external passageway will prevent water ingress and avoid severe damage to electrical panels. The water can come from regular washing of passageway or rain if the switch room is facing external of a building.

(OR)

Provide minimum 100 mm plinth for floor mounted electrical switchboard.

Alternatively, to provide plinth for floor mounted switchboard if the switch room floor cannot be raised due to building design.

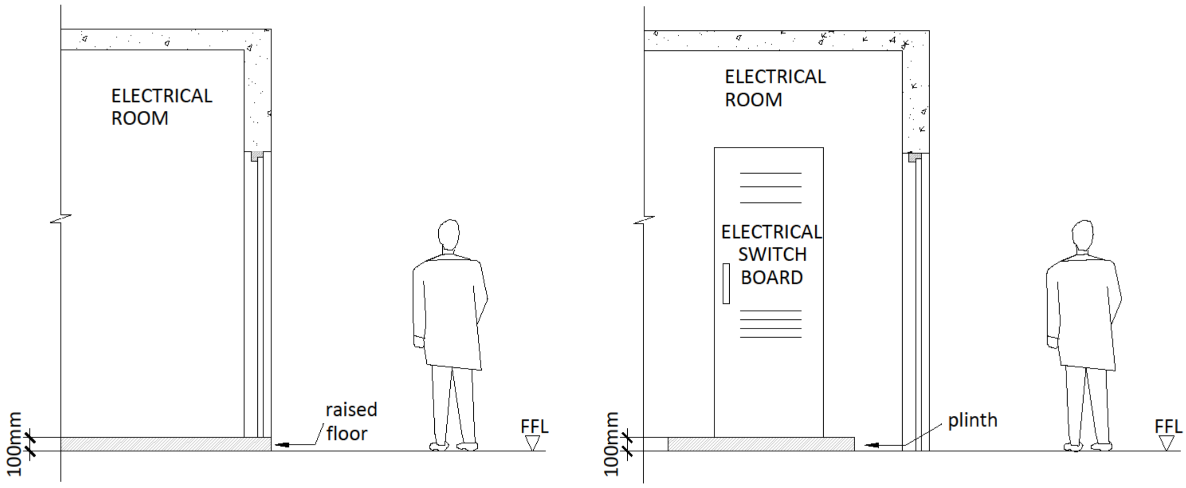


Figure 49: Raised electrical room (left) and switchboard plinth (right)

Documentation requirements

Design stage

- Tender specifications indicating the requirement.
- Drawings indicating the electrical room location and level with respect to passageway.

Verification Stage

- Shop drawings/as-built section drawings indicating the electrical room location and level with respect to passageway.
- Photographs showing implementation.

4.2.2 Reduce risk of unnoticed failure of surge arrestor located in the LT main switchboard (1 point)

Intent

To prevent failure to equipment due to lightning surge.

Design strategy and assessment: (0.5 point for each item)

a. **Use of surge arrestor with discharge indicator.**
Surge arrestor must be provided for sensitive equipment to protect against voltage surges i.e. servers, digital measuring devices, and other electronic devices etc. Lightning surge can cause damage to sensitive equipment especially electronics. Using surge arrestor with discharge indicator makes it easier to be identified if it is discharged and required for replacement to ensure the equipment is protected against surge at all times. Refer to Figure 50 below for surge arrestor with indicators.

b. **Provide BMS monitoring for surge arrestor status.**
By connecting the surge arrestor with remote monitoring to the building BMS system, timely notification could be provided to user when the arrestor is discharged. Therefore, the replacement can be done quickly to ensure the equipment are always protected against surge. Refer to Figure 50 below for surge arrestor with remote monitoring for linking to BMS system.

Note: Item b will not be applicable to projects without BMS.

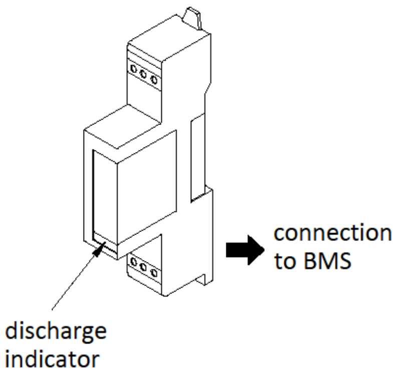


Figure 50: Surge arrestor with discharge indicator and remote monitoring

Documentation requirements

Design stage

- Tender specifications/drawings showing the discharge indicator requirement.
- BMS points schedule indicating the connection to BMS system.

Verification Stage

- As-built single line drawing and BMS points schedule showing the connection to BMS system.
- Photographs showing the discharge indicator and BMS configuration.

4.2.3 Reduce risk of failure of main LT switchboard due to overheating (1 point)

Intent

To prevent damage to switchboard due to overheating.

Design strategy and assessment: (0.5 point for each item)

a. Install heat sensor in the main LT switchboard to alert any abnormal rise in temperature with audible/visual alarm.

Loose electrical connection will cause temperature at the connection to rise beyond normal operation temperature and if not rectify timely will cause damage to the equipment e.g. circuit breaker, cable etc. and may even cause fire if it is not detected early and rectified. Installing heat sensor in the switchboard with audio/visual alarm will provide timely alert whenever the temperature is risen beyond normal operating temperature. Such automatic alert system also eliminates the need for regular visual check and enhance FM productivity.

b. Integrate sensor to building BMS system for online monitoring of temperature data.

Connecting the temperature sensor to BMS system must provide immediate notification of any abnormal increase in temperature and help in predicative maintenance. It improves FM productivity by reducing the regular physical checks.

Note: Item b will not be applicable to projects without BMS.

Documentation requirements

Design Stage

- Tender specifications/drawings showing the heat sensor requirement.
- Tender specifications/drawings/BMS IO summary indicating the connection to BMS system.

Verification Stage

- Electrical panel technical data sheet/as-built single-line drawing indicating the heat sensor location.
- BMS points schedule indicating the temperature sensor connection to BMS system.

4.3 EXTRA LOW VOLTAGE SYSTEM (3 points)

4.3.1 Provide access space for CCTV camera located at heights (1 point)

Intent

To provide ease of access to camera for maintenance.

Design strategy and assessment: (1 point)

a. Provide access to cameras located at heights (≥ 3 m) i.e. foldable poles/arms

Safe and easy maintenance access must be provided for CCTV cameras located at heights. Traditionally, a high ladder is used to access the CCTV cameras which are manpower intensive and pose safety hazard. Instead, use of alternative maintenance provision such as foldable pole which can be lowered to a reachable height during maintenance. This will help to enhance FM productivity and manpower savings. Refer to Figure 51 for foldable pole and arm.

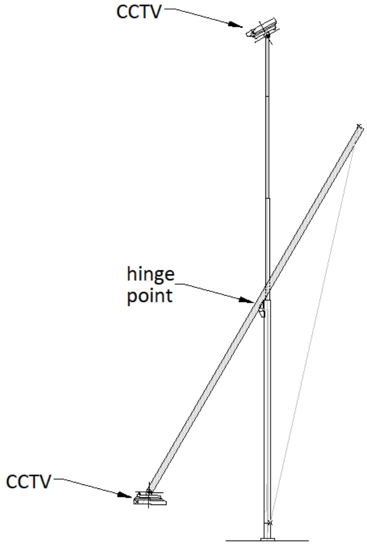


Figure 51: CCTV with foldable pole and arm

(OR)

b. Provide clear access route for mobile elevated work platforms (MEWP) to reach the camera for maintenance.

Clear and unobstructed access must be provided from the entrance to the location directly below the cameras. This clearance must include the height and width of entrance door as well as the clearance along the MEWP access path. The floor (loading and finishes) must be able to withstand the required MEWP to be deployed for the maintenance work. The deployment and operation of MEWP must comply with authority requirements. Refer to Figure 52 below for recommended clear access.

To provide clear access route of 1.8m width x 2m height and working base of 1.8 m width x 2 m length if the mounting height is less than or equal to 10.5 m. The actual clear access must depend on the proposed MEWP to be used and the manufacturer's recommended clearances through the access way.

To provide clear access route of 2 m wide x 2.8 m height and working base of 2 m width x 2 m length if the mounting height is greater than 10.5 m. The actual clear access must depend on the proposed MEWP to be used and the manufacturer's recommended clearances through the access way.

Note: Items a and b will not be applicable to projects without CCTV system.

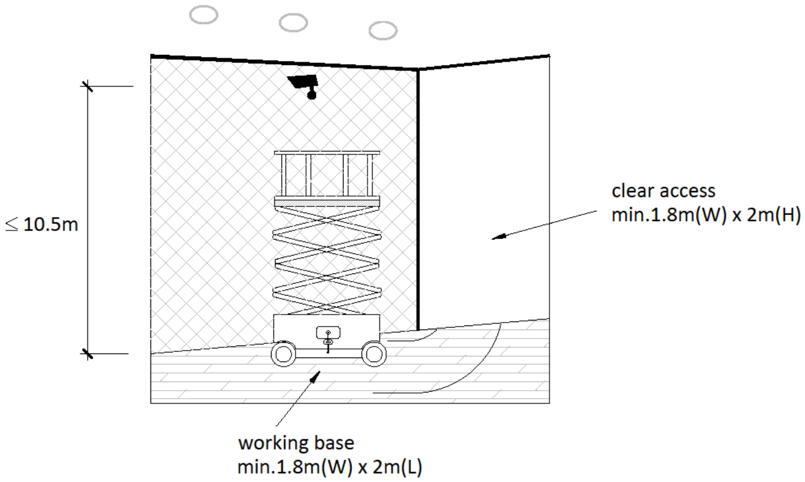


Figure 52: Clear access for CCTV with mounting height ≤10.5m

Documentation requirements

Design Stage

- Electrical layout plan showing the alternative access provisions.
- Tender specifications indicating the access provisions (i.e. foldable poles/arms etc.) or MEWP clear access route from entrance door.

Verification Stage

- As-built drawings/shop drawings showing the access provisions.
- Technical data sheet/cut sheet of foldable poles/arms highlighting the key maintainability features.
- Technical data sheet/cut sheet of MEWP with access route marking.
- Photographs showing implementation.

4.3.2 Provide flexibility for future expansion for CCTV system (1 point)

Intent

To make provision for ease of future expansion.

Design strategy and assessment: (prerequisite)

a. Provide minimum 20% spare capacity in network switch to cater for future expansion.

It is common to add new cameras while the building in operation over its life span. Lack of spare capacity in network switch may end up adding or replacing existing equipment in order to cater for the expansion. Hence it is recommended to provide at least 20% spare capacity in network switch to facilitate future addition of cameras without having to replace the existing equipment.

Note: Items a and b will not be applicable to projects without CCTV system.

Documentation requirements

Design Stage

- Tender specifications/drawings indicating the spare capacity requirement.

Verification Stage

- Shop drawing /as-built drawing indicating 20% spare capacity in the network switch for future expansion.

Design strategy and assessment: (1 point)

b. Design that allows for future addition of data storage (either local or cloud base data storage)

Addition of new cameras would lead to more data storage required; hence the system must have the flexibility to add more data storage to cater for future expansion. Alternatively, additional storage can be cloud base depending on the security policy. Such provision for future storage expansion would eliminate the need to replace the existing equipment due to expansion requirements.

Documentation requirements

Design Stage

- Tender specifications/drawings showing the requirement of future addition of data storage.

Verification Stage

- As-built drawings/shop drawings, technical data sheet, T&C forms etc. showing the implementation.

4.3.3 Reduce risk of damage to outdoor camera and other equipment due to lightning surge (1 point)

Intent

To prevent damage to equipment due to lightning surge.

Design strategy and assessment: (1 point)

a. Provide surge arrestor to all outdoor cameras.
CCTV cameras installed outdoor for external surveillance are subjected to lightning surge damaging the CCTV system leading to maintenance and safety issues. By adding lightning surge arrestor to the equipment, it will protect the camera from damage by lightning surge.

Note: The surge protection must be provided at power source and/or network switch. This item will not be applicable to projects without CCTV system.

Documentation requirements

Design Stage

- Tender specifications showing the surge arrestor requirement.

Verification Stage

- As-built schematic drawing showing the surge arrestor requirement.

4.4 LIGHTNING PROTECTION SYSTEM (1 point)

4.4.1 Reduce risk of damage of air termination tape at roof parapet wall due to operation of facade maintenance systems such as gondola (1 point)

Intent

To prevent damage to lightning tape at roof top parapet wall.

Design strategy and assessment: (1 point)

a. Avoid damage to the lightning protection system by proper design and installation of facade maintenance system.

The design of gondola system which must prevent its parts (be it fix structure or suspension steel rope) from damaging the lightning tape which is mounted on the parapet wall. It is recommended to provide sufficient if any of the gondola structure or supporting system is to be installed over the lightning tape.

Documentation requirements

Design Stage

- Tender specifications/façade access system drawings showing the requirement.

Verification Stage

- As-built lightning protection system and façade access system drawings indicating the lightning protection strip interfacing with façade access systems.
- Photographs showing the implementation.

4.5 VERTICAL TRANSPORTATION (2 point)

4.5.1 Access to lift motor room for maintenance (prerequisite)

Intent

To provide adequate access for safe and efficient lift maintenance.

Design strategy and assessment: (prerequisite)

a. Provide permanent access (staircase with handrail) to the lift motor room.

Access to the lift motor room must be considered during building design stage and unobstructed access way must be provided to the motor room for regular maintenance and repair.

Typically, the entrance to a lift motor room is via service corridor or direct access from roof level. In special cases while there is height difference (>350 mm) from the finished floor level of the corridor to the entrance of the lift motor room, permanent stairs must be provided to the lift motor room. The design must ensure the access path is not obstructed by other services.

Note: This item will not be applicable to projects without lift motor rooms.

Documentation requirements

Design Stage

- Tender specifications/drawings showing the location of lift motor room and access provision from the nearest corridor/access stairs.

Verification Stage

- As-built drawings/shop drawings indicating the access provisions.
- Photographs showing the implementation.

4.5.2 Access to roof level for equipment replacement and maintenance (1 point)

Intent

To provide lift access to roof level for maintenance staff's ease of access to main equipment such as chiller plant, VRF, water tanks, pumps and etc.

Design strategy and assessment: (1 point)

a. Provide lift access to roof for maintenance of equipment such as chiller plant and pumps.

Documentation requirements

Design Stage

- Tender drawing showing the provision of lift serving the roof.
- Tender specifications indicating that lift serves the roof.

Verification Stage

- Tender drawing and photograph showing provision of lift serving the roof.

4.5.3 Reduce lift downtime and enhance reliability (1 point)

Intent

To provide predictive maintenance for lift, improve the efficiency, and reduce the manpower requirement for lift maintenance.

Design strategy and assessment: (1 point)

a. Provide lift predictive maintenance.

Provide for real time monitoring of the lift operation and parts/components status to predict if any components would eventually lead to breakdown. Monitor key parameters such as vibration, acceleration, levelling, door jams, gaps, noise, jerk etc.

Life cycle cost analysis: baseline vs design strategy

Incremental cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
100% (No provision for baseline)	50%-55%	Up to 5%	10-11

Baseline design strategy: reactive maintenance for lift
Proposed design strategy: predictive maintenance for lift
Study period: 15 years

Yearly labour saving: 40%-50% man-hour

Documentation requirements

Design Stage

- Tender specifications/drawings showing the requirement for the provision of IoT-based infrastructure and lift predictive maintenance.

Verification Stage

- Lift maintenance contract showing the IoT based predictive maintenance.
- System architecture showing the integration of IoT based infrastructure and real-time monitoring.

4.6 SOLAR PV SYSTEM (0.5 point)

4.6.1 Reduce risk of integration issues with BMS (0.5 point)

Intent

To prevent the integration issue of the solar system with BMS.

Design strategy and assessment: (0.5 point)

a. Link PV system to BMS via open communication protocol such as Modbus, BACnet/IP for remote monitoring and data logging.

Note: This item will not be applicable to projects without BMS or PV system.

Documentation requirements

Design Stage

- PV tender drawing/specification indicating the requirement for open communication protocol and seamless integration with BMS system.

Verification Stage

- Screenshot of BMS showing the monitoring of PV panels.

SECTION 5 – LANDSCAPE

5.1 SOFTSCAPE (1.5 POINTS)

5.1.1 Reduce labour-intensive irrigation for landscape (up to 1.5 points)

Intent

To improve the operational efficiency of landscape irrigation, through optimal selection of systems and materials.

Design strategy and assessment: (prerequisite)

a. **Design for water points with maximum 20 m radius from each point.**

Note: This is for back up if auto-irrigation fails or is undergoing maintenance. Maximum radius of water point helps in managing weight of hose better.

Documentation requirements

Design stage

- Tender drawings (plan) indicating the location of water points with coverage radius for all landscape areas.

Verification stage

- As-built (construction) drawings to show implementation.
- Photographs showing the tap points in the landscape area.

Design strategy and assessment: (1.5 points)

b. **Specify rain sensor and auto-irrigation with timers.**

Note:

- *Once the rain sensor gets activated due to sufficient rainfall, the selected irrigation system will remain inactive until the hygroscopic discs inside the sensor have dried out. This dry out rate will be about the same as the soil drying rate and re-activated once the disc is dry again. The dry out rate can be set to different levels. After the rain sensor dries out, the controller will resume its normal watering schedule.*[34]
- *The rain sensors must be exposed to unobstructed rainfall as per the PUB water efficiency guidebook.*

Documentation requirements

Design stage

- Tender specification indicating auto irrigation system with rain sensor and timer.
- Plan drawing showing overall landscape area along with the type of irrigation system.
- Calculation showing the percentage of the landscape area that would be served using the system.

Verification stage

- As-built (Irrigation shop drawings) showing provision of rain sensor and the extent of implementation.
- Photographs of completed works highlighting the sensors and types of auto irrigation systems.

[34] PUB, Best practice guide in water efficiency – Buildings

Design strategy and assessment: (1 point)

c. Specify auto-irrigation with timers.
(Points cannot be scored if project has already scored for solution (b))

Life cycle cost analysis: baseline vs design strategy

Incremental Cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
Up to 5%	5% - 10%	Up to 5%	4 - 5

Baseline design strategy: Surface drip-tubing irrigation
Proposed Design strategy: Surface drip-tubing auto irrigation with timers
Study period: 5 Years
Yearly labour savings: 80% - 90% man-hour savings

Documentation requirements

Design stage

- Tender specification indicating surface/sub-surface type of auto irrigation system along with timers.
- Plan drawing showing overall landscape area along with the type of irrigation system.
- Calculation showing the percentage of the landscape area that would be served using the system.

Verification stage

- As-built (irrigation shop drawings) showing the extent of the auto-irrigation systems.
- Photographs of completed works highlighting auto irrigation systems.

Advanced effort: (1 bonus point)

Advanced effort: Implement remote monitoring system for landscape irrigation along with water metering for irrigation (+1 bonus point)

Note:

- *Irrigation water meters must be connected to the central BMS monitoring system for remote monitoring, leak detection and alert notification.*
- *Remote monitoring helps in efficient facility management with reduced manpower and conduct predictive maintenance.*

Documentation requirements

Design stage

- Tender specification/BMS I-O summary indicating the integration of irrigations system and remote monitoring capabilities.

Verification stage

- Shop drawing/ final IO summary indicating the integration of irrigation system with the BMS along with separate water metering for irrigation.
- Screenshot indicating the BMS dashboard that includes water consumption and schedule for irrigation.

5.2 HARDSCAPE (4 points)

5.2.1 Access for maintenance of underwater lighting systems (up to 2 points)

Intent

To ensure ease of access for maintenance of underwater lighting systems through appropriate design & detailing.

Design strategy and assessment: (1/0.5 point)

a. For shallow water bodies, design for easily replaceable lighting system along the inside perimeter of the structure, and

i. above the water line. (1point)

Note: Consider lighting fixture to be within arm's length from the point of access for ease of maintenance.

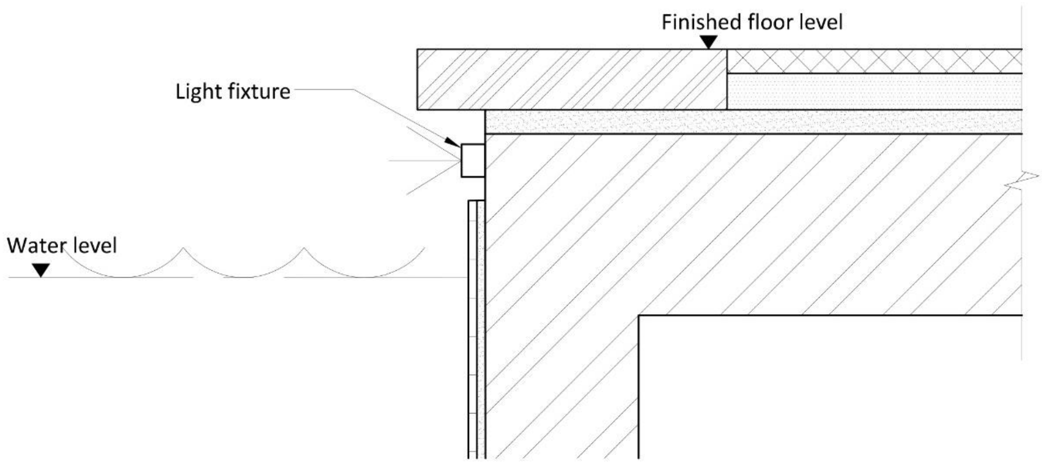


Figure 53 - Example of lighting system located above the water

ii. within a depth of 500mm below the waterline (calculated from base of light to finished floor level for in-ground water bodies/ to point of access for above-ground water bodies) (0.5 point)

Life cycle cost analysis: baseline vs design strategy

Incremental Cost	Yearly operation and maintenance cost saving		Total life cycle cost saving	Simple payback (years)
10% - 15%	60% - 65%		10% - 15%	6 - 7

Baseline design strategy: Lighting fixture with integrated driver submerged in water
Proposed design strategy: Lighting fixture with integrated driver outside water
Study period: 10 Years
Yearly labour savings: 90% -100% man-hour savings

Documentation requirements

Design stage

- Tender drawings (plan and section) indicating the location of the lighting fixtures.

Verification stage

- As-built (construction) drawings to show the implementation.
- Photographs of completed works.

Design strategy and assessment: (1)

b. For swimming pools , design lighting fixture within a depth of 500mm and along the perimeter. (1 point) *(calculated from base of light to finished floor level for in-ground water bodies/ to point of access for above-ground water bodies)*

Note:

- *Consider providing minimal services underwater to avoid draining the water body for maintenance.*
- *Provide electrical cable longer than 1 m to facilitate ease of light replacement outside the water.*

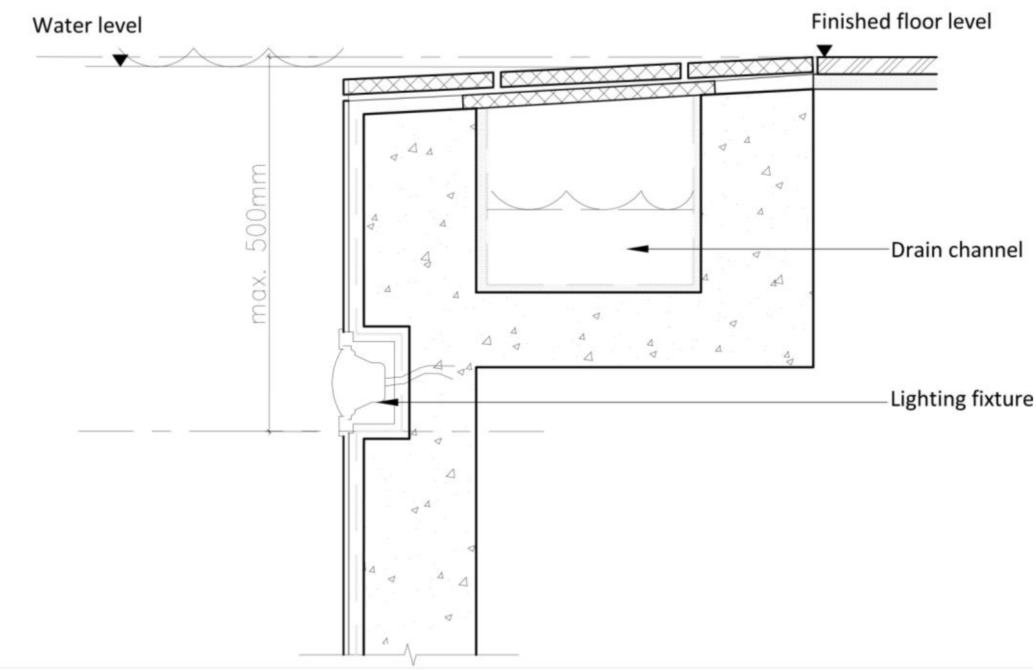


Figure 54 - Section showing the light fixture at accessible distance for repair and maintenance

Documentation requirements

Design stage

- Tender drawings (plan and typical section) indicating the depth of lighting fixture from the point of access.

Verification stage

- As-built (construction) drawings to show implementation.
- Photographs of completed works.

5.2.2 Reduce risk of damage/degradation to outdoor fixed landscape furniture (up to 1 point)

Intent

To reduce the frequency of repair and replacement of weather-exposed furniture, through optimal selection of materials.

Design strategy and assessment: (1 point)

a. Specify for engineered wood with water absorption rate not exceeding 0.5%.

Note:

- *As an alternative to natural wood, engineered wood offers a practical middle ground and can be used to replace timber in outdoor applications. Due to its inherent characteristics such as resistance to weather, moisture and termites and low maintenance, they are used widely as a substitute for natural wood.*[35]
- *The selected engineered wood should comply with ASTM D1037-93.*
- *This criterion assesses outdoor decking and fixed furniture, including those within standalone structures.*

Life cycle cost analysis: baseline design strategy vs proposed design strategy

Incremental Cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
15% - 20%	65 % - 70 %	Up to 5%	7-8

Baseline design strategy: Engineered/Reconstituted/Composite deck with higher water absorption rate
Proposed design strategy: Engineered/Reconstituted/ Composite deck with water absorption rate less than 0.5%
Study period: 10 years
Yearly labour savings: 80% - 90% man-hour savings

Documentation requirements

Design stage

- Tender specifications indicating engineered wood along with maximum water absorption rate.
- Plan drawing highlighting the location of application.

Verification stage

- As-built (landscape) drawings to show implementation.
- Relevant technical specification on the maximum water absorption property of the material.
- Delivery order for the selected material.

Design strategy and assessment: (1 point)

b. Specify for anti-corrosion coating or stainless steel or aluminium for metal selections.

Note:
- The selected anti-corrosion coating should comply with ISO 12944-2018 Corrosivity Category C3, Durability High
- Stainless Steel Grade should minimally be SS 304

[35] BCA Good industry practices, Composite fibre plastic material chapter 11, Page 82

Documentation requirements

Design stage

- Tender specification indicating the type of metal and/or anti-corrosion coating complying with ISO 12944 corrosivity category 3.
- Plan drawing showing the location of application.

Verification stage

- As-built (shop drawings) to show implementation.
- Relevant technical specification of the selected anti-corrosion coating complying with ISO 12944 corrosivity category 3
- Delivery order of the selected metal selections.

Worked Example 12:

Brightville hospital has an outdoor healing park that is opened to the public, patients, and staff. Wooden benches have been provided as part of the landscape design and is placed at various spots in the park. Of the total 20 wooden benches, 4 are made of balau wood while the remaining 16 are made of reconstituted wood.

- Proportion of outdoor benches made of reconstituted wood
  = 16 no. / 20 no. = 90% (≥15%)

NOTE: *Under the assessment category of Cat 2, full points will be scored when the proportion of one item is >85%. Hence, the use of benches made of reconstituted wood, which is 90% of all outdoor benches, will score 100% of the points.*

5.2.2 Reduce risk of damage/degradation to outdoor landscape furniture (up to 0.5 point)	Points	Assessment category	**Used in Project**	**Points Scored**
a. Specify for engineered wood with water absorption rate not exceeding 0.5%.	0.5	Cat 2	√	100% * 0.5 = 0.5
b. Specify for anti-corrosion coating or stainless steel or aluminium for metal selections.	0.5	Cat 2	×	0
Score for 5.2.3 in hardscape =				0.5

The total points for ***5.2.2 under Hardscape*** is = 0.5 point

5.2.3 Access for maintenance beneath decking (1 point)

Intent

To ensure ease of access for maintenance of services beneath deck, through appropriate design & detailing.

Design strategy and assessment: (1 point)

a. Design decks with demountable fixture system for maintenance of services beneath and for general cleaning.

Note: The entire deck area must be demountable for maintenance.

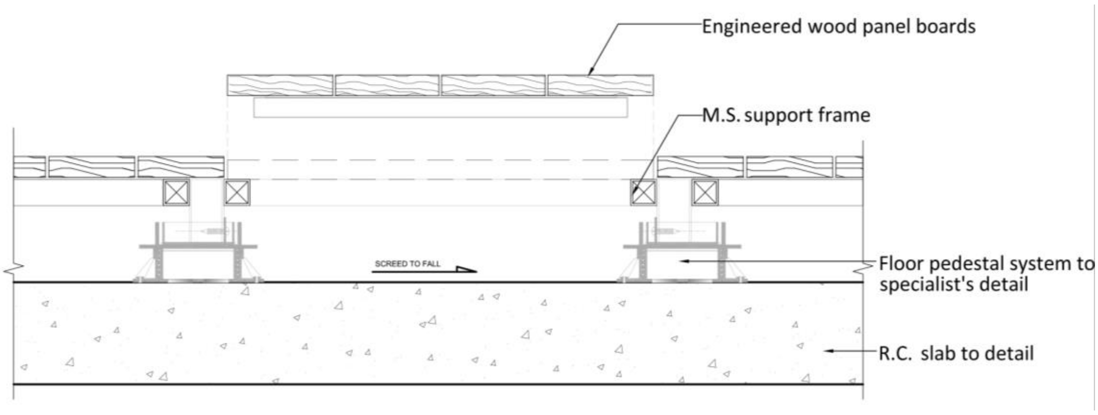


Figure 55 - Typical section showing demountable fixture deck system

Documentation requirements

Design stage

- Tender drawings (plan and section) indicating the decking system along with fixing methodology for demountable strategies.

Verification stage

- As-built (shop drawings) to show implementation.
- Photographs showing sample of the deck in demountable position.

5.3 VERTICAL GREENERY

5.3.1 Access to all parts of vertical greenery for maintenance and replacement of perished plants (prerequisite)

Intent

To ensure ease of access for safe and efficient maintenance of vertical greenery.

Design strategy and assessment: (prerequisite)

a. Provide direct maintenance access to all vertical greenery both indoor and outdoor, e.g. catwalk, ladder, access corridor, MEWP, etc.

Note:

- *Landing surface/space must be level, stable and dimensionally adequate for safe, and effective deployment of equipment[36].*
- *The frequency of maintenance tasks as well as the need for safety features – such as maintenance access, anchorage points and safety lines – should be considered in the façade greenery design.*
- *For maintenance walkways, consider a minimum width of 600mm.*

[36] CS E11:2014 Guidelines on Design for Safety of Skyrise Greenery, NParks Centre for Urban Greenery & Ecology, 2014n

- *Avoid use of scaffolding as an access strategy.*

Life cycle cost analysis: baseline vs design strategy

Incremental Cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
45% - 50%	85% - 90%	50% - 55%	4 -5

Baseline design strategy: Green wall access through MEWP
Proposed design strategy: Green wall access using permanently installed metal catwalk
Study period: 30 Years
Yearly labour savings: 60% - 70% man-hour savings

Documentation requirements

Design stage

- Plan/elevation/schematic drawings demonstrating access and working clearance for MEWP at the location. Please refer to BCA's façade access design guide for more details on the submittals.

Verification stage

- Extract from maintenance strategy report indicating MEWP's access and working clearance.

5.4 ROOF, AND SKY TERRACES, AND PLANTER BOXES ON BUILDING EDGE/FAÇADE (1.5 points)

5.4.1 Access for landscape on roofs and sky terraces (1 point)

Intent

To ensure ease of access for safe and efficient maintenance of landscape on roof top and sky terraces.

Design strategy and assessment: (prerequisite)

a. Provide direct maintenance access to landscape on all roof and sky terraces.

Note:
- *Direct maintenance access refers to systems such as staircase or lift access to roof/sky terrace.*
- *Service lift to roof/sky terrace floors, should be designed with spatial and loading capacity to facilitate transport of access equipment and other materials for maintenance.*[37]

Documentation requirements

[37] BCA Façade access design guide, 4.1 Roof Access, 4.1.1 Vertical access to roof

Design stage

- Tender drawings (plan and section) showing the access to roof for landscape maintenance.

Verification stage

- As-built drawings to highlight the maintenance access.

Design strategy and assessment: (prerequisite)

b. For planters more than 1.8m wide, provide minimally 300 mm obstruction free maintenance pathway inside the planter box.

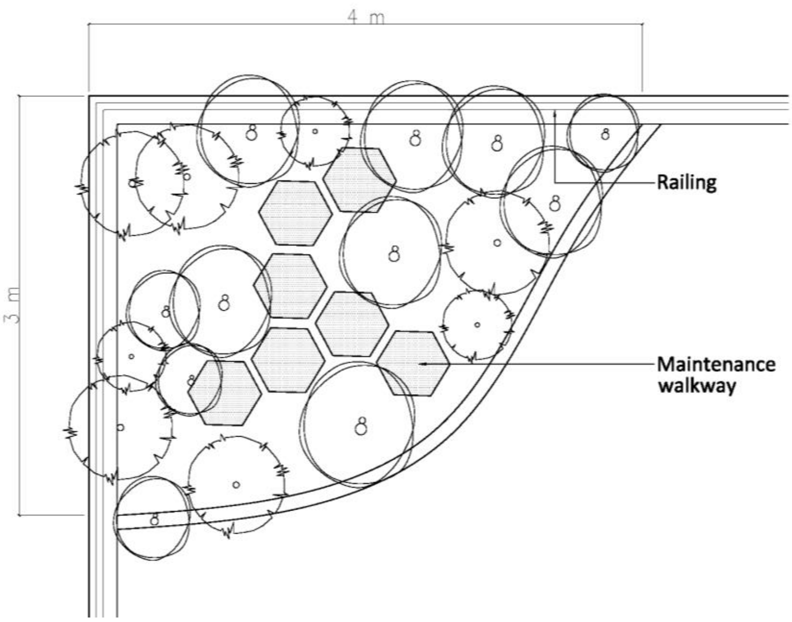


Figure 56 - Maintenance walkway for planter box more than 1.8m wide

Documentation requirements

Design stage

- Tender drawings (plan and section) showing extent of planter box and obstruction free maintenance pathway.

Verification stage

- Photographs showing the path inside the planter box.
-

Design strategy and assessment: (1 point)

c. For trees: Provide 5 m clear pathway from building edge to tree trunk.[38]

Note:

- *For infant trees, the expected height is to be mentioned in the design stage.*

[38] Handbook on developing sustainable high-rise gardens – Safe design of trees on rooftop. pg24
CS E09:2012 Guidelines on Planting of Trees, Palms and Tall Shrubs on Rooftop, 2.2.1

This criterion is applicable to above L1.

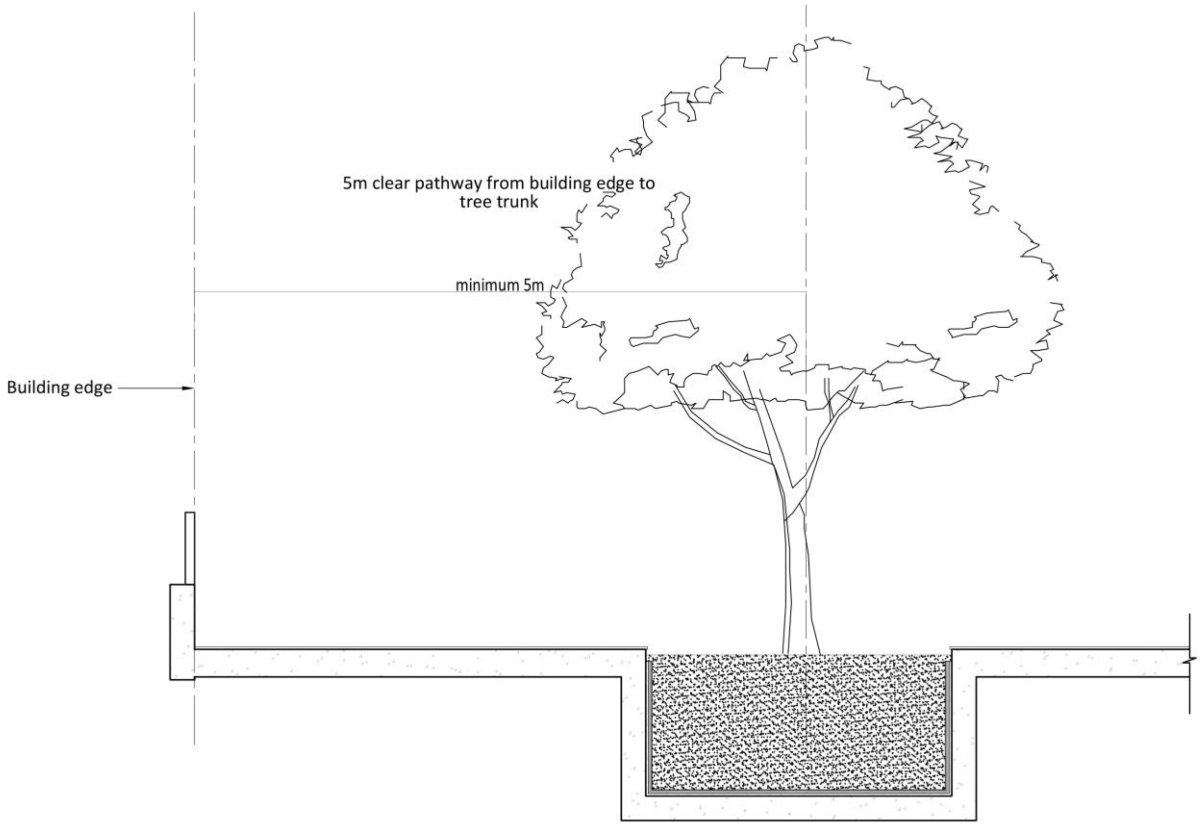


Figure 57 - Typical section showing buffer zone required for trees

Documentation requirements

Design stage

- Tender drawings (plan and section) showing the clear maintenance pathway of 5m for trees from the inner side of the building edge.

Verification stage

- As-built drawings showing the maintenance pathway.
- Photographs highlighting the distance from the tree trunk to the building edge.

5.4.2 Access to planter boxes on building edge (0.5 point)

Intent

To ensure ease of access for safe and efficient maintenance of landscape on building edges.

Design strategy and assessment: (0.5 point)

a. Provide minimally 600 mm access walkway to planter boxes for maintenance[39].

Note:
- *Consider providing access from non-tenanted spaces.*
- *Safety line and guard rail must be provided as per guideline.[40]*

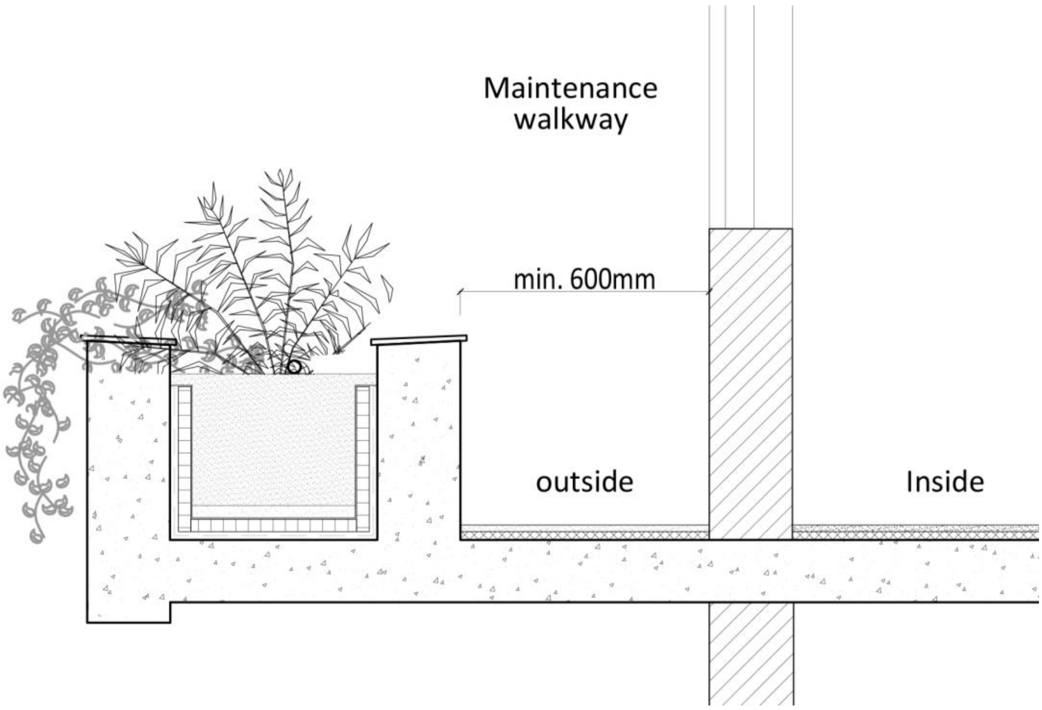


Figure 58 - Planter box with maintenance walkway

Documentation requirements

Design stage

- Tender drawings (plan and section) showing the planter box and the provision of accessibility pathway for landscape maintenance.

Verification stage

- As-built drawings to show implementation.
- Photographs of the completed works indicating the maintenance access.

[39] CS E11:2014 Guidelines on Design for Safety of Skyrise Greenery, NParks CUGE

[40] Workplace Safety and Health Guidelines

5.5 WATER RETAINING STRUCTURE (2 points)

5.5.1 Reduce risk of water leakage from swimming pools/water bodies (up to 2 points)

Intent

To reduce the frequency of repair and maintenance of water bodies due to water leakage, through optimal selection of materials and design & detailing.

Design strategy and assessment: (2 points)

a. Specify prefabricated water retaining structures, e.g. fibreglass reinforced or stainless-steel pool.[41]

Note: As per NEA Code of practice for the design and management of aquatic facilities, "aquatic facilities should be constructed from materials that are non-toxic to humans under normal condition of use, impervious, enduring, capable of withstanding design stresses, and provide a watertight structure."

Documentation requirements

Design stage

- Tender specification indicating the prefabricated water retaining structure.
- Plan and sectional drawings showing the location of water retaining structure.

Verification stage

- As-built (shop drawings) to show implementation.
- Photographs of completed works.

Design strategy and assessment: (2 points)

b. For concrete pools - specify integral liquid waterproofing admixture in concrete mixes and additional layer of waterproofing layer on the inside of the pool.

Documentation requirements

Design stage

- Tender specification indicating the integral waterproofing admixture system and the type of waterproofing layers on the inside of the pool.
- Plan drawing showing the location of the waterbody/swimming pool.
- Typical sectional drawing showing the layers of waterproofing.

Verification stage

- As-built drawings to show implementation.
- Delivery order for the specified internal water proofing.
- Photographs of waterproofing system application during the construction stage.

[41] SS 556: 2010 Code of practice for the design and management of aquatic facilities.
NEA Code of practice for the design and management of aquatic facilities

Advanced effort: (1.5 bonus points)

Advanced effort: Provision of maintenance slab below the swimming pool with headroom access of minimum 2.0 m[42].

Documentation requirements

Design stage

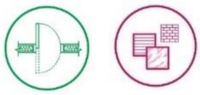
- Tender drawing (plan) showing the location of waterbody.
- Sectional drawings to highlight the double slab with minimum 2.0 m clearance for access.

Verification stage

- As-built drawings to show implementation.
- Photographs of completed works.

5.6 STANDALONE STRUCTURES (1.5 points)

5.6.1 Reduce water ponding and degradation of outdoor standalone structures, e.g. pavilions (up to 0.5 point)



Intent

To reduce the frequency of repair and maintenance of standalone structures through optimal selection of materials and design & detailing.

Design strategy and assessment: (prerequisite)

a. **Design for outdoor standalone structure's roof slope to be not gentler than 15 degrees for efficient water runoff**

Note: The above gradient of 15 degrees is indicative. Designers may propose alternative gradients to meet the intent of effective water drainage.

Documentation requirements

Design stage

- Tender drawing (plan) showing the location of the standalone structure.
- Detail drawings/specifications showing the roof slope of the outdoor standalone structure.

Verification stage

- As-built (shop drawings) to show implementation.
- Photographs of completed works.

---

[42] BCA – Approved Document – section C.3.2.1 - The headroom of every room, access route and circulation space must not be less than 2.0 meters. Design for maintainability guide: PART II - H1.6 Headroom access

Design strategy and assessment: (0.5 points)

b. Design to avoid direct contact of steel base with the ground (raised by at least 100mm) to prevent corrosion and entrapment of moisture and dirt.

Example - Protect steel bases at ground by providing conical concrete upstand in water ponding areas. *(Point cannot be scored if already scored in solution 1.5.2)*

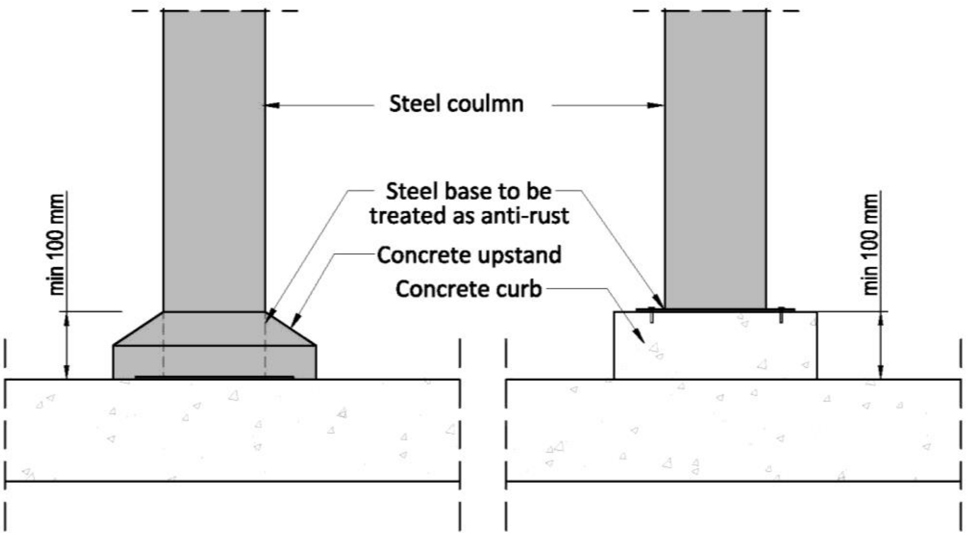


Figure 59 - Concrete upstand protection for steel base

Documentation requirements

Design stage

- Tender drawings (plan and section) showing the location of the vertical structural support and the weather protection detailing.

Verification stage

- As-built drawings/shop drawings to show implementation.
- Photographs of the concrete upstand or concrete curb after implementation.

5.6.2. Reduce risk of warping/deterioration of ceiling panel system on outdoor standalone structures (up to 1 point)

Intent

To reduce frequency of repair and replacement of weather-exposed ceiling panels through optimal selection of materials.

Design strategy and assessment: (1 point)

a. Specify suspended metal panel modular ceiling system, e.g. baffle metal panels and metal mesh panels.

Note:

- *Panels should be designed to prevent sagging and withstand wind loads.*
- *Panels should be sized such that they can be easily handled by one person.*

Life cycle cost analysis: baseline vs design strategy

Incremental Cost	Yearly operation and maintenance cost saving	Total life cycle cost saving	Simple payback (years)
40% - 45%	75% - 80%	5% – 10 %	6 - 7

Baseline: Moisture resistant monolithic gypsum ceiling board
Design strategy: Metal panel suspended modular ceiling
Manpower savings: 90 - 100% man-hour savings

Documentation requirements

Design stage

- Tender specification indicating the type of metal suspended modular ceiling panel.
- Reflected ceiling plans showing the extent of metal false ceiling.

Verification stage

- As-built drawings showing the extent of implementation.
- Relevant technical material specification for the selected metal panel ceiling and the anticorrosion property of the material.
- Delivery order for the selected ceiling panels.
- Photographs of completed works.

Design strategy and assessment: (1 point)

b. Specify moisture-resistant suspended non-metallic modular ceiling panels with water absorption rate not exceeding 5 %.

Note: Water absorption rate indicates how much moisture a specific material is likely to absorb. Ceiling panels with lower water absorption rate absorbs less moisture and reduces deterioration. The selected ceiling panel should comply with ASTM C473 for the water absorption test.

Documentation requirements

Design stage

- Tender specification indicating the moisture resistant material and maximum water absorption rate for suspended ceiling panel.
- Reflected ceiling plans showing the extent of the moisture-resistant false ceiling.

Verification stage

- As-built drawings to show the extent of implementation.
- Relevant technical material specification or product performance test results for the moisture resistant property of the ceiling panel for the water absorption rate.
- Photographs of completed works.

Design strategy and assessment: (1 point)

c. Specify for open ceiling design.

Documentation requirements

Design stage

- Tender specification indicating the open ceiling system for the selected areas.
- Reflected ceiling plans showing the extent of open ceiling.

Verification stage

- As-built (interior) drawings to show implementation.
- Photographs of completed works showing the open ceiling spaces.

SECTION 6 – SMART FM

6.1 GOOD PRACTICES (UP TO TOTAL 2 POINTS)

6.1.1 Good practices that could be considered during design stage

Intent

Good practices that could be considered during design stage

Design strategy and assessment: (up to 2 points)

a. **Building Management System ready for integration with Smart FM**
   - i) **Provide open communication protocol such as BACnet, MODBUS, etc for ease of integration with other Smart FM systems. (Prerequisite)**
   - ii) **Adoption of a common and consistent naming convention for BMS data points which is handed over to the building owner. (1 Point)**
   - iii) **Provision of automated and schedule exports of data points to commonly used file formats which enables exchange of data between systems. For example, data export to analytics or optimization software. (1 Point)**
   - iv) **Provision of documentation during handover stage to ensure operational continuity. (Prerequisite)**

Documentation requirements

Design Stage

- BMS Tender specification capturing the open communication protocol requirements
- BMS Tender specification / tender drawings specifying the requirement for common and consistent naming convention for BMS data points
- BMS tender specification stating the requirement automated and scheduled export of data points to commonly used file formats (eg. CSV or XLS).
- BMS tender specification stating that handover documentation must comprise of write-up on system control strategy, control logic diagram, BMS network schematic showing device locations and network addresses, operations maintenance manual (OMM) and training guides

Verification Stage

- Documentary evidence stating that open communication protocol is provided
- BMS naming convention including list of abbreviations
- Sample of data extracted from BMS in CSV or XLS format
- Documentary evidence indicating that BMS handover documentation have been handed over to Developer / Facilities Manager.

6.2 CYBERSECURITY (Applicable to both BMS and FMS System)

6.2.1 Lack of Cyber security leading to data theft and economic impact

Intent

To provide enhanced protection to internet-connected system and protect organisations against cyber threats

Design strategy and assessment: (1 point)

a. Implement a risk-based cyber security assessment conducted by building owner's IT department/cyber security consultant

Building OT system i.e., BMS and FMS system must be governed by Information Security Management System ("ISMS"). These are some basic cyber security requirements that should be included in the ISMS;

i) Minimum of two network tiers for BMS and FMS – web/application tier ("demilitarised zone or DMZ") and data tier separated by firewall that appropriately configured to block direct access to database from external network.

ii) Up-to-date anti-virus software in all machines.

iii) Firewalls to assess communication with 3rd-party services.

iv) Encryption of critical data at rest (stored data) and data in transit (transmitted data);

v) User access must have Individual user authentication and multi-level grouping to regulate the access. The login authentication to be password protected.

vi) Conducting of regular Vulnerability Assessment & Penetration Testing ("VAPT") and remediation of all critical, high and medium security issues; VAPT should minimally cover the latest OWASP Top 10 vulnerabilities.

vii) System audit log or audit trail to record data changes and system access.

viii) Install two-factor Authentication.

Note:

i) Risk assessment involves taking steps to understand any flaws or vulnerabilities in the network and steps taken to remediate the threat. The above-mentioned list of key cyber security provisions is non-exhaustive. Building owner/cyber security consultant to evaluate the building specific cyber security requirements.

Documentation requirements

Design Stage

- Company's IT policy capturing the risk-based cyber security assessment requirement for BMS AND/OR FMS system.

Verification Stage

- Risk-based cyber security assessment report highlighting the key risks, proposed cyber security framework and formulate remediation steps.

Additional recommendation for guidance:
The typical cyber security risk assessment report should include following steps;

i) **Take inventory of systems and devices** – *the report should document all device that are connected to the network i.e., computers, servers, routers, printers, API's etc. Any hardware that is linked to the data network can potentially become the source of a cyber intrusion.*

ii) **Identify potential weaknesses and threats –** *Assessing the different cyber-attacks that potentially target the system network must be thoroughly validated. Potential threats include:*
- *Unauthorized access to your network*
- *Misuse of information or data leakage*
- *Failed processes*
- *Data loss*
- *Disruption of service*

iii) Determine the risk impact - List all potential risks and rate them on a scale of low, medium, and high risk.
- Low-risk items might include servers that contain public information but no private data and where such servers are connected to an in-house network.
- Medium-risks items might be related to offline data storage at a specific physical location.
- High-risk items might include payment or customers' personal information stored in cloud software

iv) Develop and set cybersecurity controls – With the understanding of the potential risk, set-up security controls and protocols which can greatly reduce risks and improve compliance. The security controls include some of the solutions listed above.

v) Evaluate the effectiveness and repeat – Conduct the cybersecurity risk analysis at least annually to ensure that the cyber security controls are Upto date. Also, it is recommended to conduct regular Vulnerability Assessment & Penetration Testing ("VAPT") and remediation of all potential threats; VA to minimally cover the latest OWASP Top 10 vulnerabilities

Additional resources: https://securityscorecard.com/blog/how-to-perform-a-cyber-security-risk-analysis

Design strategy and assessment: (1 point)

b. The organisation is assessed by an independent party and certified to comply with 1 of the following certifications.

a. **ISO 27001**, the International Information Security Standard
b. **SOC 2** certification, American Institute of Certified Public Accountants.
c. **IEC 62443**, Industrial communication networks - IT security for networks and systems.

Documentation requirements

Verification Stage

- Certificate issued by the independent party.

6.3 INNOVATION (3 POINTS)

6.3.1 Adopt innovative technologies that improve FM labour efficiency and service delivery. (up to 3 points)

Intent

To use innovative technologies to improve operation and maintenance and enhance labour efficiency.

Design strategy and assessment: (prerequisite)

a. **Adopt at least one Smart FM solution (Type 1 or 2) within project. Score at least 1 point from 6.3.1b or c.**

Design strategy and assessment: (1 point each)

b. **Type 1 – Use of digitised workflow automation to streamline the workflow, productivity and service delivery:**

Digitalized Workflow Automation: When triggered by a feedback or incident, automatically initiates a process that tracks, monitors, and closes the feedback or incident.

Example applications are as follows:

1. Remote monitoring systems with sensors that which will alert FM team on fault detection and critical incident alerts
2. Video analytics with incident detection that would alert security team of any abnormalities
3. Application that allows for automated temperature adjustment in accordance to user feedback
4. CMMS software for FM workflow automation
5. Smart toilets
6. Smart bins
7. Smart monitoring system for fire extinguishers
8. Smart exit lights
9. Software platform for defects management
10. Software platform for handover of as-built drawings

Documentation requirements

Design Stage

- Tender specifications / tender drawings for Type 1 Smart FM solutions
- Developer's project brief for Type 1 Smart FM solutions that are not finalised during design stage

Verification Stage

- System write up for the Type 1 Smart FM solutions implemented
- Photos, screenshots and as-built drawing showing the extent of implementation

Design strategy and assessment: (1 point each)

c. **Type 2 – Use of data analytics and artificial intelligence for system optimization and predictive maintenance:**

i) Diagnostics AI: Able to identify system deviations and diagnose potential causes.

ii) Predictive AI: Able to diagnose problems and predict future states of assets and systems.

Example applications are as follows:

1. M&E equipment condition monitoring with sensors and analytics for preventive/conditional-based maintenance (e.g. monitoring of embedded sensors in chiller or VRF CU to predict mechanical wear and failure)
2. Fault detection diagnostics to find failed or improperly operating equipment (e.g. using abnormalities in IAQ readings or deviation from set points to relate equipment faults)

Documentation requirements

Design Stage

- Tender specifications / tender drawings for Type 2 Smart FM solutions
- Developer's project brief for Type 2 Smart FM solutions that are not finalised during design stage

Verification Stage

- System write up for the Type 2 Smart FM solutions implemented
- Photos, screenshots and as-built drawing showing the extent of implementation

6.4 ADVANCED SMART FM (4 POINTS)

6.4.1 Advanced Smart FM – Integrated and aggregated Smart FM solutions that improve FM labour efficiency and service delivery (up to 4 points)

Intent

To explore smart design solutions to streamline the maintenance process and improve labour efficiency.

Design strategy and assessment: (up to 4 points)

a. **Type 3 – Integration across systems (1 point each):**

Integration across multiple systems/FM services to optimize resource deployment and utilization across multiple systems/FM services

Example applications are as follows:

1. Use of lift traffic and carpark gantry data to forecast and streamline cleaning regimes
2. Integration of CCTV with access control system for intrusion detection
3. Integration between CCTV system and Fire Alarm System to promptly identify occurrences of false alarms

Documentation requirements

Design Stage

- Tender specifications / tender drawings for Type 3 Smart FM solutions

Verification Stage

- System write up for the Type 3 Smart FM solutions implemented
- Photos, screenshots and as-built drawing showing the extent of implementation

Design strategy and assessment: (1 point each)

b. Aggregated Smart FM Solution

Building owners can explore areas where economies of scale can be achieved through aggregation of FM solutions.

Example applications are as follows:

1. For building owners with a portfolio of buildings, Smart FM solutions or FM functions such as cleaning and security can be aggregated across the portfolio of buildings for a better overview and management of resources.
2. Building owners with a single development may explore aggregation through FM companies and solution providers through outcome-based contracts. FM companies and solution providers can better manage resources to meet service demands through the aggregation of buildings in a district.

Documentation requirements

Design Stage

- Tender specifications / Developer's project brief highlighting the aggregation of Smart FM solutions or FM functions across a portfolio of buildings.
- Tender specifications / Developer's project brief highlighting the aggregation of FM services within a district through outcome-based contracts.

Verification Stage

- Documentary evidence extracted from relevant FM contracts.

6.5 ROBOTICS AND AUTOMATION (3 POINTS)

6.5.1 Design for robotics and automation (R&A) (up to 3 points)

Intent

To design for and explore the use of robotics and automation to streamline maintenance processes and improve labour efficiency.

Design strategy and assessment: (3 points)

a. Design for Robotics and Automation

Building infrastructures should be designed to optimise robot capabilities such as their range of mobility, ease of completing tasks, and ability to navigate its work environment.

Identifying the robots of interest to be deployed and recognising their corresponding level of autonomy is important in planning for suitable infrastructure that would cater to the robots.

Example use of FM robots could include the following:

- Cleaning robot e.g. façade, floor, window, toilet
- Concierge robot
- Façade inspection robot/drone
- Landscape management robot e.g. lawn mowers
- Pest management robot e.g. detection, monitoring, extermination
- Security robot
- Waste management robot

Note: Robot-inclusive design principles can be categorised into the following 5 principles:

1. Activity
Optimise traffic flow involving people, goods, and robots through the selection of best mechanisms suited for deployment, operation, and storage.

Examples include:
- Designate and design docking points for easy deployment and storage of robot
- Demarcate clear robot-only zones where the robot and human's workspaces are not intended to overlap

2. Accessibility
Provide infrastructure for safe navigation, good connectivity between areas and access for the robot within its work zone.

Examples include:
- Provide sufficient clearance (width and height) for movement of robot to, during and from its operation
- Minimise obstructions such as uneven surfaces or bumps along robot's pathway
- Provide slopes with appropriate gradient for robot movement instead of steps to remove barriers to movement

3. **Observability**
Provide infrastructure that allows for good visibility of environment for robot perception, navigation, and localisation.

Examples include:
- Utilise high-contrast materials to aid robots in analysing relevant data and discerning boundaries
- Implement location-tagging technologies (e.g., QR codes, barcodes, symbols) to assist in robot localisation within its work environment
- Select appropriate building materials and finishes to minimise glare or excessive reflection of light which may disrupt robot sensors

4. **Manipulability**
Design for the robot ability's to move or rearrange objects in the environment by grasping, carrying, pushing, dropping, or lifting them using its end effectors / grippers

Examples include:
- Design appropriate devices such as handles or buttons on objects that requires robot manipulation (e.g., provide handles for better grip)

5. **Safety**
Ensure the safety of both humans and robots operating in the same workspace

Examples include:
- Design features that demarcate no-entry zones for robots (e.g. detection markers at stairs, steep slopes or escalators etc.)
- Select appropriate floor finishes to prevent slippage

Credits for robot-inclusive design principles: SUTD

Documentation requirements

Design Stage

- Developer's design brief indicating on the type of robotics and the extent of implementation
- Design report (Architectural, Structural, Mechanical & Electrical, Façade and etc) highlighting the key features of the building which would facilitate the implementation of robotics

Verification Stage

- Screenshots / photos showing the actual implementation.

CHAPTER 4: RESPONSIBLE PARTIES FOR KEY MAINTENANCE ITEMS

The table below outlines the primary responsible parties for each Key Maintenance Items (KMIs). The Developer / Building Owner must direct the various responsible parties (where applicable to the project) to collaborate and comply with the KMIs.

KEY MAINTAINENCE ITEMS		Responsible parties
SECTION 0 – GENERAL		
	Promote inclusion of Design for Maintainability (DfM) at planning and design stage	Client / Facility Manager / Architect / M&E Consultant/ BIM manager / Other specialists
SECTION 1 – ARCHITECTURAL EXTERIOR		
1.1	General Facade	
1.1.1	Reduce risk of water ingress and streaking on façade	Architect / Façade consultant
1.1.2	Access for maintenance of façade	Architect / Façade consultant
1.1.3	Access for maintenance to façade, soffit and roof of sky bridges	Architect / Façade consultant
1.2	Cladding system: Tile/Stone/Metal/Others	
1.2.1	Reduce risk of water ingress and streaking on façade	Architect / Façade consultant
1.3	Curtain Wall	
1.3.1	Reduce risk of water ingress and streaking on façade	Architect / Façade consultant
1.4	Masonry and Lightweight Concrete Panels	
1.4.1	Reduce risk of water ingress and efflorescence formation	Architect / Façade consultant
1.4.2	Reduce risk of façade flaking /peeling /cracking /blistering	Architect / Façade consultant
1.5.1 Façade Features / other façade considerations		
1.5.1	Direct access to all protruding façade features, e.g. canopies, sunshade, niches, fins, ledges, photovoltaic panels, BIPV etc.	Architect / Façade consultant
1.5.2	Reduce risk of corrosion of exposed steel structures	Architect
1.5.3	Reduce risk of water ingress in open joint cladding (i.e. cladding serving as a decorative feature and not as a water barrier)	Architect / Façade consultant
1.5.4	Reduce risk of tile/stone from detaching off facade	Architect / Façade consultant
1.6	Entrance Lobby	
1.6.1	Reduce risk of water ingress at entrances	Architect
1.7	Roof	

1.7.1	Reduce risk of water ponding on roofs	Architect
1.7.2	Reduce risk of waterproofing decay/failure on concrete roofs	Architect / Water proofing specialist
1.7.3	Reduce risk of corrosion on metal roofs	Architect / Metal roof specialist
SECTION 2 – ARCHITECTURAL INTERIOR		
2.1	Floors	
2.1.1	Reduce risk of damage to floors in common areas within the building	Architect / Interior consultant
2.1.2	Reduce maintenance works in common areas within the building	Architect / Interior consultant
2.2	Ceilings	
2.2.1	Access to services within double slab areas for maintenance purposes	Architect / Interior consultant
2.2.2	Access to services within the ceiling in non-tenanted indoor spaces	Architect / Interior consultant
2.2.3	Access to ceiling for maintenance	Architect
2.2.4	Reduce risk of warping / deterioration of ceiling panel systems that are weather-exposed, e.g. sky terraces, entrance porches, corridors and canopies	Architect / Interior consultant
2.3	Wet Rooms and Storage	
2.3.1	Provide permanent space to store cleaning tools and toilet supplies	Architect
2.3.2	Reduce risk of mould and fungus formation on walls in wet rooms	Architect / Interior consultant
2.3.3	Reduce risk of damage to toilet cubicle partitions and enable ease of cleaning	Architect / Interior consultant
2.3.4	Reduce risk of water spill on floor, and splashing and soap dripping on the counter and floor	Architect / Interior consultant
2.3.5	Reduce the need to replace entire mirror glass pane when damaged	Architect / Interior consultant
2.3.6	Reduce degradation of false ceiling system in wet rooms	Architect / Interior consultant
2.4	Basement	
2.4.1	Reduce risk of water ingress/seepage in basement	Architect / C&S consultant
2.5	Loading Bay/Back of House Service Areas	
2.5.1	Reduce damage caused by impact on walls and columns in vehicular ramps, and loading bay areas	Architect

2.5.2	Reduce damage to walls, columns and floors at back of house (within the building)traffic delivery areas	Architect
SECTION 3 - MECHANICAL		
3.1	**Chiller Plant**	
3.1.1	Access to chiller plant room for equipment replacement	Architect / M&E consultant
3.1.2	Access to equipment requiring frequent maintenance	Architect / M&E consultant
3.1.3	Reduce risk of corrosion and dust invasion in cooling tower	M&E consultant
3.1.4	Reduce risk of oil/grease deposit on the cooling tower fins	Architect / M&E consultant
3.1.5	Reduce risk of fouling issue and improve condenser water quality	M&E consultant
3.1.6	Reduce risk of dust and debris settlement inside the cooling tower basin	M&E consultant
3.2	**Unitary Air Conditioning System – Variable Refrigerant Flow (VRF)**	
3.2.1	Access to VRF outdoor units	Architect / M&E consultant
3.2.2	Avoid damage to the refrigerant pipe and insulation	M&E consultant
3.3	**Air Distribution System**	
3.3.1	Access space for maintenance of air distribution system	Architect / M&E consultant
3.3.2	Reduce risk of water ponding and algae growth in the AHU room	Architect / M&E consultant
3.3.3	Reduce risk of choke of condensate drain pipes	Architect / M&E consultant
3.3.4	Reduce frequency of replacement for AHU filters	M&E consultant
3.3.5	Avoid frequent re-alignment of fan parts i.e. pulley, bearings and belts	M&E consultant
3.4	**Domestic Water Supply**	
3.4.1	Access space for maintenance of water tank	Architect / M&E consultant
3.5	**Sanitary System**	
3.5.1	Access provision and design detailing for sanitary pipes for ease of maintenance	M&E consultant
3.5.2	Reduce risk of chokes in the sanitary pipe	Architect / M&E consultant
3.6	**Fire Protection System**	

3.6.1	Prevent the lack of flexibility for maintenance and testing of sprinkler system	M&E consultant
3.6.2	Reduce risk of damage and periodic replacement of fire-rated boards due to exposure to high humidity and water	M&E consultant
3.7	Building Management System	
3.7.1	Access space above false ceiling for maintenance of sensors and actuators	M&E consultant / Architect
3.7.2	Access to control panels for regular maintenance	M&E consultant
SECTION 4 - ELECTRICAL		
4.1	Lighting System	
4.1.1	Reduce frequency of light replacement	M&E consultant / Architect / Interior Design consultant / Lighting Consultant
4.1.2	Reduce risk of light flickering	M&E consultant / Architect / Interior Design consultant / Lighting Consultant
4.1.3	Reduce risk of LED light colour shift	M&E consultant / Architect / Interior Design consultant / Lighting Consultant
4.2	Power Distribution	
4.2.1	Reduce risk of water ingress into electrical room	Architect/ M&E consultant
4.2.2	Reduce risk of unnoticed failure of surge arrestor located in the LT main switchboard	M&E consultant
4.2.3	Reduce risk of failure of main LT switchboard due to overheating	M&E consultant
4.3	Extra Low Voltage System	
4.3.1	Provide access for CCTV camera located at heights	M&E consultant / Architect / Interior Design consultant
4.3.2	Provide flexibility for future expansion for CCTV system	M&E consultant
4.3.3	Reduce risk of damage to outdoor camera and other equipment due to lightning surge	M&E consultant
4.4	Lightning Protection System	
4.4.1	Reduce risk of damage of air termination tape at roof parapet wall due to operation of façade maintenance systems such as gondola	M&E consultant / Architect / Façade consultant
4.5	Vertical Transportation	
4.5.1	Access to lift motor room for maintenance	M&E consultant / Architect
4.5.2	Access to roof level for equipment replacement and maintenance	M&E consultant / Architect

4.5.3 Reduce lift downtime and enhance reliability	M&E consultant
4.6 Solar PV System	
4.6.3 Reduce risk of integration issues with BMS	M&E consultant
SECTION 5 - LANDSCAPE	
5.1 Softscape (3.5 points)	
5.1.1 Reduce labour-intensive irrigation for landscape	Landscape Architect
5.2 Hardscape (5.5 points)	
5.2.1 Access for maintenance of underwater lighting systems	Architect / Landscape Architect
5.2.2 Reduce risk of damage/degradation to outdoor fixed landscape furniture	Landscape Architect
5.2.3 Access for maintenance beneath decking	Landscape Architect
5.3 Vertical Greenery	
5.3.1 Access to all parts of vertical greenery for maintenance and replacement of perished plants	Architect / Landscape Architect/ Façade consultant
5.4 Roof and Sky Terraces	
5.4.1 Access for landscape on roof and sky terraces	Architect / Landscape Architect
5.4.2 Access to planter boxes on building edge	Architect / Landscape Architect
5.5 Water retaining structure	
5.5.1 Reduce risk of water leakage from swimming pools/water bodies	Architect / C&S consultant
5.6 Standalone structure	
5.6.1 Reduce water ponding and degradation of outdoor standalone structures	Architect / Landscape Architect
5.6.2 Reduce risk of warping/deterioration of ceiling panel system on standalone structure	Architect / Landscape Architect
SECTION 6 – SMART FM	
6.1 Good practices	
6.1.1 Good practices that could be considered during design stage	Architect/ M&E consultant
6.2 Cybersecurity	
6.2.1 Lack of cyber security leading to data theft and economic impact	Client/ Facility Manager

6.3	Innovation	
6.3.1	Adopt innovative technologies that improve FM labour efficiency and service delivery	Client/ Architect/ M&E consultant/ Facility Manager
6.4	Advanced Smart FM	
6.4.1	Advanced Smart FM – Integrated and aggregated Smart FM solutions that improve FM labour efficiency and service delivery	Client / M&E consultant / Facility Manager
6.5	Robotics and Automation	
6.5.1	Design for Robotics and Automation (R&A)	Client/ Architect/ M&E consultant / Facility Manager