Building and Construction Authority

An MND Statutory Board

Version 1.0

GOOD PRACTICE GUIDE FOR DESIGN, INSTALLATION AND MAINTENANCE OF BUILDING FIXTURES

Disclaimer

This Guide is a summary of good practices that may be adopted for the design, installation and maintenance of building fixtures, and does not purport to be exhaustive or applicable to all situations. This Guide does not constitute professional advice. Please seek advice from suitably qualified professional advisers.

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History of amendments

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Jurong Town Corporation (JTC)

Housing & Development Board (HDB)

The Institution of Engineers, Singapore (IES)

Association of Consulting Engineers Singapore (ACES)

Singapore International Facility Management Association (SIFMA)

Singapore Land Group Limited

Capitaland Investment Limited

Contents

1 INTRODUCTION

Building fixtures are commonly installed in all parts of commercial buildings and some areas in shared residential spaces. These fixtures include suspended ceiling, air-conditioning and mechanical ventilation (ACMV) fixtures, Mechanical, Electrical and Plumbing (MEP) fixtures such as water pipes electrical services, and signages. Building fixtures are commonly supported by hangers, brackets and metal frames that are fastened to ceiling soffit or walls.

This Guide has been developed by BCA in consultation with industry stakeholders to provide a collection of good practices for the design, installation and maintenance of building fixtures. This Guide is suitable to be used by building owners and responsible parties such as tenants, managing agents (including Town Councils) and service providers (including consultants, suppliers, installer, etc.) who are responsible for the design, installation and maintenance of building fixtures.

The publication of these guidelines aims to reduce the number of incidents involving the collapse of building fixtures due to ill-designed fixture supports and frequent oversight on the maintenance of building fixtures. These incidents not only pose a safety risk to the public accessing the spaces below, but also incur hefty time and monetary cost for the rectification works required. Deteriorating fixtures will also require extensive overhaul besides compromising the building's aesthetics.

Each chapter in this Guide is divided into four sections detailing the common causes of collapse, the design & installation, the maintenance & inspection, and lastly the inspection guidelines. Finally, checklists are attached at the end of each chapter for use by maintenance personnel.

This Guide is not meant to be a definitive technical manual, as the manufacturers' specifications should always be followed, but a guide on the good practices that should be adopted to ensure the integrity of the fixtures and the safety of the public.

2 SUSPENDED CEILING

Suspended ceiling is a fixture used extensively in our buildings. Adequate design, proper installation and regular maintenance of the suspended ceiling and its supporting structures are required to ensure that it can adequately serve its purpose throughout its lifespan and not pose a safety risk to the public.

This chapter explains the common causes of the collapse of suspended ceilings and recommends good practices for the design, installation and maintenance of suspended ceilings. More emphasis to be given to suspended ceilings installed in public spaces and walkways including those with high ceilings, long spans and those located at the building periphery and bridges that could be exposed to natural elements such as wind gusts and rainwater. Attention should also be given to existing suspended ceilings with timber supporting frames and hangers using nails as they are prone to corrosion and deterioration, and areas that are exposed to weathering effects.

Examples of suspended ceilings are shown in Figure 2-1 to Figure 2-4.

Figure 2-1: Gypsum Suspended Ceiling in Office Spaces

Figure 2-2: Metallic Suspended Ceiling in Shopping Mall

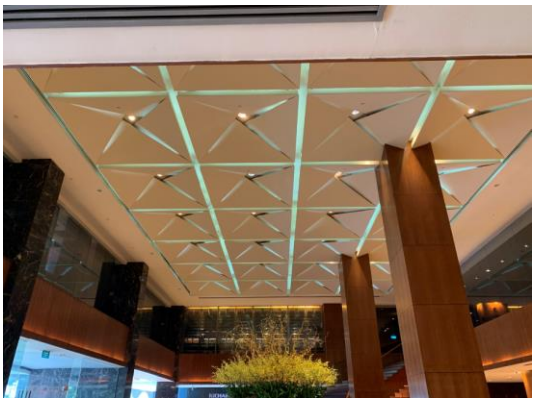


Figure 2-3: Decorative Suspended Ceiling in Hotel Lobby

Figure 2-4: Decorative Suspended Ceiling in Shopping Mall

2.1 Common Causes of the Collapse of Suspended Ceilings

Lack of maintenance and improper use of suspended ceilings can cause the deterioration of the suspended ceiling and its supporting structures, which may result in a partial or full collapse of the suspended ceiling. Examples of collapsed suspended ceilings are shown in Figure 2-5 to Figure 2-9, and the common causes of collapse are tabulated below.

Figure 2-5: Collapsed Suspended Ceiling Due to Water Ingress and Rusty Screws

Figure 2-6: Collapsed Suspended Ceiling Due to Spalling Concrete at Ceiling Soffit

Figure 2-7: Collapsed Suspended Ceiling Due to Additional Load from Cabinet

Figure 2-8: Collapsed Suspended Ceiling Due to Progressive Failure of Panel Support

Figure 2-9: Collapsed Suspended Ceiling at Building Periphery Due to Failure of Timber Supporting Frame with Nails

COMMON CAUSES OF THE COLLAPSE OF SUSPENDED CEILINGS
1. Inadequate inspections and ineffective maintenance plans (e.g., inspection done on an irregular/prolonged interval or inspection carried out by untrained personnel, etc.) that lead to undetected or unaddressed defects and issues in the suspended ceiling, such as: a. Prolonged sagging; b. Water ponding[1]; c. Corrosion; d. Water stains or water seepage; e. High humidity and moisture in the environment which can cause corrosion and deterioration to suspended ceiling panels and their supports; f. Termite infestation; g. Spalling and crack observed on the supporting concrete elements[2]; and h. Other forms of wear and tear.
2. Inappropriate use of the suspended ceiling space for maintenance, such as maintenance personnel crawling on the suspended ceiling causing overloading and damage to the suspended ceiling components or their supporting structures.
3. Inappropriate alteration or removal of the supporting structures, such as hangers, of the suspended ceiling;
4. Inappropriate addition of fixtures or equipment (e.g., cabinets, pipes, display screens, signages, etc.) to the suspended ceiling such that additional loads are imposed beyond the allowable loads that the

[1] Water leakages and ponding in the suspended ceiling space could have been caused by defects of the roof, plumbing or air-conditioning and mechanical ventilation (ACMV) systems, which could have redirected water into unintended regions such as the suspended ceiling space.

[2] Concrete spalling generally manifest at the building periphery and exteriors, floors below roof structures exposed to weather elements and wet areas prone to water ingress from rain and other sources. These areas are sometimes hidden from view by suspended ceilings and if unattended to for a long time, could lead to a large extent of spalled concrete dislodgements.

suspended ceiling and its supporting structures are designed to carry. For example, hanging of cables on the suspended ceiling's suspension and hangers, or resting network, communication or switch equipment on the grids.
5. Poor workmanship and improper installation of the suspended ceiling.

2.2 Good Practices for the Design and Installation of Suspended Ceilings

The industry should adopt the following good practices when designing and installing suspended ceilings and their supporting structures to ensure the safety of building users and maintenance personnel.

RECOMMENDATIONS (DESIGN AND INSTALLATION)
1. Conform to established standards[3] for the design, specification, installation and testing of the suspended ceiling. These standards include: a. British/European Standard (BS EN 13964:2014 Suspended Ceilings – Requirements and Test Methods; and b. Australian/New Zealand Standard (AS/NZS 2785:2020 Suspended Ceilings – Design and Installation)
2. The British/European Standard (BS EN 13964:2014 Suspended Ceilings – Requirements and Test Methods) includes the following salient requirements on design of a suspended ceiling and its supporting structures: a. A uniform imposed load of 0.25kN/m^2 (25kg/m^2) should be applied over the whole of the suspended ceiling, and a concentrated load of 0.9kN (90kg) should be applied to produce maximum stresses in the suspended ceiling and its supporting structures in accordance to Eurocode 1: EN 1991-1-1-2008;

[3] Please refer to the prevailing applicable version of the Codes and Standards.

b. The safety factor when tested in accordance to BS EN 13964:2014 should be a minimum of 2.5;

c. Suspended ceiling should not be used to support the additional load from a partition unless specifically designed to do so.

3. The Australian/New Zealand Standard (AS/NZS 2785:2020 Suspended Ceilings – Design and Installation) includes the following salient requirements on design of a suspended ceiling and its supporting structures :

   a. The suspended ceiling is designed and installed such that it remains structurally safe for a period of at least 15 years;

   b. The frame and suspension used for the suspended ceiling and its supporting structures are made of durable and corrosion resistant material;

   c. Design and component choices for suspended ceiling installed at the exterior of the building should be suitable for its intended use taking into consideration the influence from the higher wind load and the effect of external weathering;

   d. The suspended ceiling and its supporting structures are designed such that the failure or removal of a single hanger or support does not cause progressive collapse of the system;

   e. Screw fasteners used for tension connections are designed to prevent pull-out, pull-through and over tightening;

   f. Screw fasteners in tension should not be used in material less than 3mm thick, unless the system can be tested to be adequate; and

   g. Screw fastener is able to achieve a minimum of three full thread penetration into steel.

4. The following design considerations should be incorporated in the design of the suspended ceiling.

   a. Provision of redundancies to accommodate unexpected additional live loads and to prevent progressive collapse of the system that such as those due to water ponding, displacement of heavy fixtures

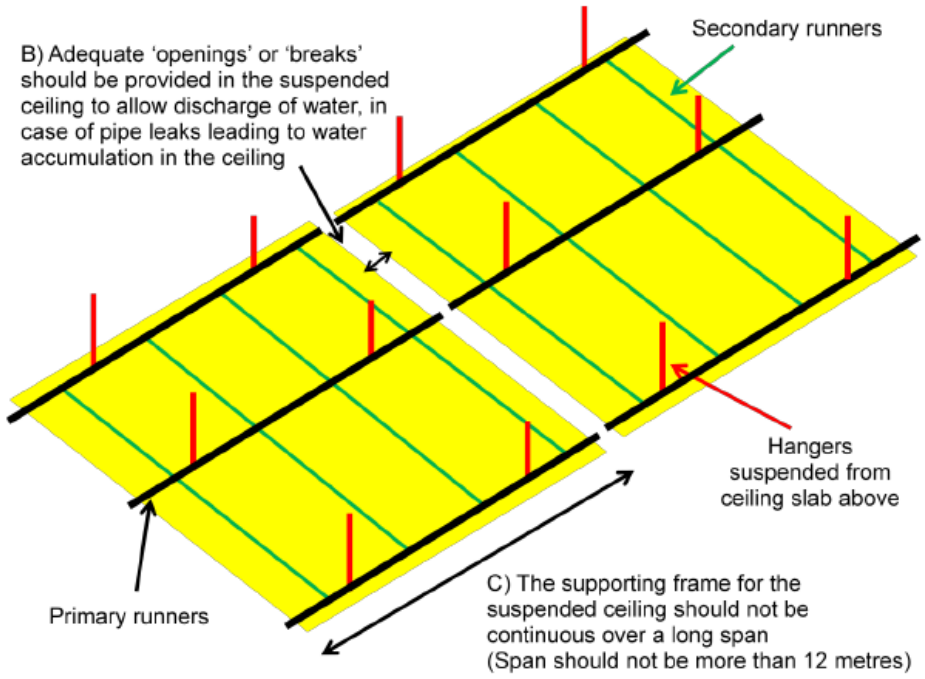
onto the ceiling board, and localised failure of supports, hangers, frames or panels;

b. The supporting frames of the suspended ceiling should not be continuous over a long span and should be designed with a span not exceeding 12 metre to minimise the risk of a large-scale and progressive collapse of the suspended ceiling[4];

c. A means to discharge unexpected accumulation of water on the suspended ceiling (e.g., from burst water pipes) such as providing adequate openings or breaks along the suspended ceiling; and

d. Provision of access panels where required for maintenance[5] should be designed for ease of manoeuvre and access.

Figure 2-10 below illustrates the good practices in the design and installation of suspended ceilings.



Simple representation of suspended ceiling
(This diagram is for illustrative purposes only)

Figure 2-10: Good Practices in the Design and Installation of Suspended Ceilings

[4] Please refer to Figure 2-10.
[5] Please refer to the Design for Maintainability (DfM) Guide for more information.

5. The Australian/New Zealand Standard (AS/NZS 2785:2020 Suspended Ceilings – Design and Installation) includes the following salient requirement on installation of the suspended ceiling and its supporting structures :

    a. Hangers should not be bent or kinked to avoid building services and obstructions during installation;

    b. The suspended ceiling and its supporting structures should not be used to support other building fixtures and vice versa;

    c. When hangers are obstructed by building services, secondary members should be installed;

    d. Suspended ceiling supported from purlins and trusses should have its main rails laid perpendicular to the purlins;

    e. Lighting fixtures installed in the suspended ceiling should not overload or cause the ceiling system to sag, and should be fitted within the grid or to the grid;

    f. The suspended ceiling and its supporting structures are able to accommodate movement caused by changes in temperature and humidity;

    g. Fixing to steel soffit of composite slab should be carried out in accordance with the guidelines and requirements of the specific product;

    h. Stainless steel rivets should not be used in tension to connect the top or bottom of hangers. It should only be used to resist shear force; and

    i. Screw fastener used to secure the ceiling panel should not be overtightened to prevent indentation on the panel.

6. The following should be considered for the anchors, screws and rivets used for installation.

    a. Corrosion resistant material such as stainless-steel of minimum grade SS304 should preferably be used for the anchors, screws and rivets subjected to external weathering or wet conditions. For indoor

space with dry condition, the use of galvanised-steel fasteners shall be a minimum requirement;

b. Design and installation of anchors to conform to BS 8539:2012 - Code[6] of Practice for Selection and Installation of Post-Installed Anchors in Concrete and Masonry;

c. The required embedment depth for the anchor installation into the reinforced concrete structural elements should extend beyond the concrete cover to the reinforcement layer when measured from the base material, and this required embedment depth should exclude the thickness of any plaster layer;

d. Anchor used should be suitable for anchoring into concrete (e.g., cracked-approved anchor) to account for microcracks in concrete;

e. Consult the supplier, manufacturer, or a registered Professional Engineer in the Civil Engineering discipline for the suitable type of anchors, screws and rivets to be used;

f. Procure anchors, screws and rivets from reliable manufacturers and suppliers;

g. Adhere to the installation guide provided by the manufacturers;

h. Attend courses on anchor installation by established course provider; and

i. Carry out testing of anchors according to BS 8539:2012 and the latest edition of the normative reference published by the Construction Fixings Association Guidance Note – Procedure for Site Testing Construction Fixings.

7. Engage the supplier, manufacturer, specialist or a registered Professional Engineer in the Civil Engineering discipline to design and supervise the installation, alteration or modification to the supporting structure of the suspended ceiling.

[6] Please refer to the prevailing applicable version of the Codes and Standards.

8. Procure suspended ceiling and its supporting structures from reliable manufacturers and suppliers who provide warranty and maintenance support.

2.3 Good Practices for the Inspection and Maintenance of Suspended Ceilings

Poorly maintained and defective suspended ceilings pose a safety risk to the public. Building owners and responsible parties should carry out regular inspections and maintenance of suspended ceilings and adopt the following good practices.

RECOMMENDATIONS (MAINTENANCE AND INSPECTION)

1. Schedule for regular inspection of the suspended ceilings and its supporting structures, and keep inspection records for future reference. The following recommendations may be considered:

    a. Carry out visual inspection on an annual basis and a full inspection at intervals of not more than three years as recommended in BS 8210:2020 Code[7] of Practice for Facilities Maintenance Management or as recommended by the manufacturer, whichever is earlier;

    b. Check validity/expiry of warranty for product and its supporting structures;

    c. Maintenance and inspection may be carried out by in-house maintenance team, or by external maintenance firm engaged by the building owners or responsible parties. Building owners or responsible parties may also engage a specialist or a Professional Engineer (PE) in the Civil Engineering discipline to carry out the inspection;

    d. Inspection for fixtures above suspended ceiling can be carried out every 10 to 15 metres depending on the visibility of fixtures and the line of sight from inspection points of suspended ceiling;

[7] Please refer to the prevailing applicable version of the Codes and Standards.

e. Place emphasis on suspended ceiling over high human traffic areas and high density public assembly areas where members of the public would be present for a substantial length of time (e.g., waiting/seating areas, lobbies, entrance, food courts, etc.);

f. Place emphasis on suspended ceiling subjected to unfavourable environmental conditions such as exposure to wind, rain, moisture, condensation, exhaust, heat and vibration that may accelerate the deterioration of fixtures;

g. Keep records of any known maintenance problems and previous rectifications carried out on the suspended ceiling fixtures. Useful plans, sketches, photographs and tabulations could also be kept to illustrate the findings of the inspection;

h. Adequately photograph and document details of any new defects (e.g., location, defect observed, repair work that was carried out, etc.);

i. Implement a maintenance plan to identify defects[8] early, conduct a detailed investigation to ascertain the root causes of such defects, and promptly repair the defects;

j. Building owners and responsible parties are recommended to incorporate monitoring and predictive elements, such as sensors and artificial intelligence, into their Building Management Systems (BMS) to collect and analyse trends and operating conditions of the suspended ceiling and its supporting structures and its components. Parameters that may be monitored include leakages, humidity, vibration, etc.; and

k. Engage the supplier, manufacturer, specialist or a registered Professional Engineer to address any defects that warrant further investigation.

2. Adhere to the operation and maintenance manual provided by the supplier or manufacturer of the suspended ceiling, which may include the following:

[8] Building owners and responsible parties are advised to promptly investigate and address the root cause of defects especially defects such as spalling concrete, water seepage and excessive accumulation of water.

a. Replacement of missing or damaged ceiling boards with the appropriate type and model;

b. Replacement of deteriorated or detached anchors with stainless-steel anchors;

c. Repair and seal the suspended ceiling components damaged by water ingress;

d. Tightening of loose nuts and hangers; and

e. Consult the supplier, manufacturer, specialist or a registered Professional Engineer in the Civil Engineering discipline for any repair, replacement or alteration to the suspended ceiling and its supporting structures.

3. Promptly inspect and address any maintenance issues reported by tenants or members of the public, such as water leaks from roof, plumbing and air-conditioning and mechanical ventilation systems.

2.4 Inspection Guidelines for Suspended Ceilings

Building owners and responsible parties should be vigilant and look out for any of the following warning signs of damage and deterioration of the suspended ceilings, supporting structures and the structural elements to which they are installed.

SIGNS OF DAMAGE OR DETERIORATION
1. Building owners and responsible parties should look out for the following signs when inspecting the suspended ceilings. a. Sagging, deformed or uneven suspended ceiling components or dislodgement of any suspended ceiling panel or component; b. Presence of water stains, efflorescence, moulds, and water leaks; c. Any fixture or equipment that may have dislodged and is imposing its self-weight onto the suspended ceiling;

d. Additional fixtures such as lighting, piping, ducts and diffusers that do not have independent supports and are imposing additional loads onto the suspended ceiling; and

e. Review the analytical and predictive data in the Building Management Systems (BMS) to identify defects in the operation and condition of the equipment and its components. Data includes leakages, temperature and humidity fluctuation, excessive vibration, etc.

2. Building owners and responsible parties should look out for the following signs when inspecting the **supporting structures** of the suspended ceilings.

    a. Sagging, deformed, uneven, bent, kinked, loose or dislodged supporting structures, such as hangers, frames and bolts and nuts;

    b. Inappropriate alteration or removal of the supporting structure, such as hangers, frames and bolts and nuts; and

    c. Signs of corrosion, rust or other forms of deterioration and damage on the supporting structure.

3. Building owners and responsible parties should look out for the following signs when inspecting the **structural elements** to which the suspended ceilings are installed such as columns, beams and slab.

    a. Concrete crack lines;
    b. Spalling concrete;
    c. Corrosion;
    d. Water stains or water seepage;
    e. Termite infestation; and
    f. Other signs of deterioration.

4. Should there be any defects observed, building owners and responsible parties are advised to contact the supplier, manufacturer, specialist or a registered Professional Engineer for advice and repair/replacement.

2.5 SUSPENDED CEILING INSTALLATION CHECKLIST

Building: Company:

Block / Storey: Name of Installer:

Date of Installation: Name of Supervisor:

S/N	Description	✓/×/NA	Remarks
1.0	**Suspended Ceilings Installation**		
1.1	Approved shop drawing and calculation endorsed by a Professional Engineer (PE) is submitted and available on installation site		
1.2	Hangers are not to be bent or kinked in an attempt to avoid building services and obstructions during installation		
1.3	The suspended ceiling and its hangers are not used to support other building fixtures and vice versa. e.g., improper use of suspended ceiling's suspension and hangers to hang cables, cabinets, pipes, display screens, signs or resting network, communication or switch equipment on the grids		
1.4	Secondary members are installed according to design when hangers are obstructed by building services		
1.5	Suspended ceiling supported from purlins and trusses has its main rails laid perpendicular to the purlins		
1.6	Lighting fixtures installed in the suspended ceiling does not cause the ceiling system to sag, and are fitted within the grid or to the grid		
1.7	The suspended ceiling and its supporting structures are able to accommodate movement caused by changes in temperature and humidity		
1.8	Fixing to steel soffit of composite slab is carried out in accordance with the approved drawings and the requirements of the specific product		

1.9	Stainless steel rivets are not used in tension to connect the top or bottom of hangers. Note: It should only be used to resist shear force		
1.10	Screw fasteners used to secure the ceiling panel are not overtightened to prevent indentation on the panel		
1.11	Screw fastener penetration into steel has a minimum of three full threads		
1.12	Suspended ceiling is not to support a partition unless specifically designed for in the approved drawings		
1.13	Access panels for maintenance are adequately provided in accordance with approved drawings		
2.0	**Connections and Anchors**		
2.1	Anchors, screws and rivets are made of corrosion resistant material; preferably made of stainless-steel with minimum grade SS304 when used in area subjected to external weathering or wet condition, and minimally made of galvanised-steel when used in indoor space with dry condition		
2.2	The required embedment depth of anchors should extend beyond the concrete cover and exclude the thickness of any plaster layer		
2.3	Suitable type of anchors are used in accordance to the approved drawings as prescribed by the Professional Engineer		
2.4	Anchors, screws and rivets are procured from reliable manufacturers or suppliers and installed in accordance with the manufacturer’s installation guidelines		
2.5	Anchor installer is well trained and has attended courses on anchor installation by established course provider		

2.6 SUSPENDED CEILING MAINTENANCE AND INSPECTION CHECKLIST

Building: Company:

Block / Storey: Name of Supervisor:

Inspection frequency: Date of Inspection:

S/N	Description	✓/×/NA	Remarks
1.0	**Documentation**		
1.1	A set of approved drawings, manufacturer/supplier's operation and maintenance manual (OEM) and warranty documentation are available		
1.2	Review records of any known maintenance problems and previous rectifications carried out on the fixtures, including data from the Building Management Systems (BMS) such as leakages, temperature and humidity fluctuation, excessive vibration, etc.		
1.3	Place emphasis on suspended ceiling over high human traffic and public assembly areas such as waiting/seating areas, lobbies, entrance, food courts, etc.		
1.4	Place emphasis on suspended ceiling subjected to unfavourable environmental conditions such as exposure to wind, rain, moisture, condensation, exhaust, heat and vibration that may accelerate the deterioration of fixtures		
1.5	Photograph and document details of any new defects (e.g., location, defect observed, repair work that was carried out, etc.)		
2.0	**Suspended Ceilings Panels**		
2.1	No uneven, sagging, deformed, damaged, corroded or dislodged suspended ceiling		

2.2	No water stains, efflorescence, moulds, or water leaks		
2.3	No fixture or equipment such as lighting, piping, ducts and diffusers is dislodged and imposing its self-weight onto the suspended ceiling panel or frame		
3.0	**Supporting Structures – Hangers, Frames, And Connections**		
3.1	No missing, loose, bent, kinked, corroded, sagging, damaged or inappropriately altered supporting structures such as hangers, frames, bolts, nuts, screws, clips, brackets, etc.		
3.2	No hanger is used to support other building fixtures not designed for (e.g., improper use of suspended ceiling's suspension and hangers to hang cables, cabinets, pipes, display screens, signages or resting network, communication or switch equipment on the grids)		
3.3	No signs of other forms of deterioration and damage on the hangers, frames and connecting bolts and nuts		
4.0	**Structural Elements – Columns, Beams, And Slab**		
4.1	No concrete crack lines around the connections		
4.2	No spalling concrete		
4.3	No corrosion on steel structure		
4.4	No water stains or water seepage		
4.5	No termite infestation		
4.6	No other signs of deterioration		

Note:

Should there be any defects observed, building owners and responsible parties are advised to contact the supplier, manufacturer, specialist or a registered Professional Engineer for advice and repair/replacement.

3 AIR-CONDITIONING AND MECHANICAL VENTILATION (ACMV) FIXTURES

Air-conditioning and mechanical ventilation (ACMV) fixtures have become an indispensable part of a building to provide a comfortable living and working environment for building users. The components used for ACMV fixtures are generally heavier than those used for other types of fixtures. Therefore, incidents that involve the collapse of an ACMV fixture could pose a safety risk to the public.

This chapter explains the common causes of the collapse of ACMV fixtures and recommends good practices for the design, installation and maintenance of ACMV fixtures. More emphasis to be placed on ACMV fixtures installed in public spaces, venues with high ceilings of more than 3m such as cinemas, auditoriums and convention centres, and areas that are exposed to weather elements.

Examples of ACMV fixtures are shown in Figure 3-1 to Figure 3-4.

Figure 3-1: ACMV System and Fixtures

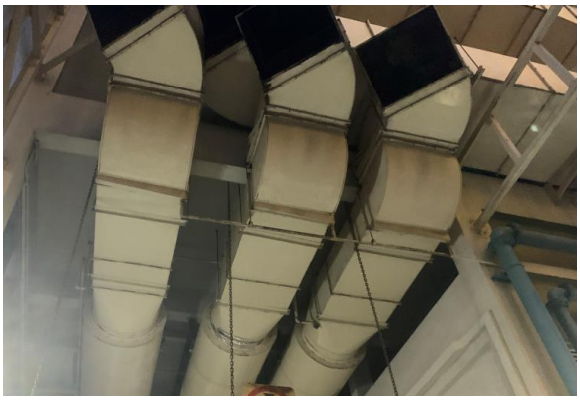


Figure 3-2: ACMV System and Fixtures

Figure 3-3: ACMV System and Fixtures

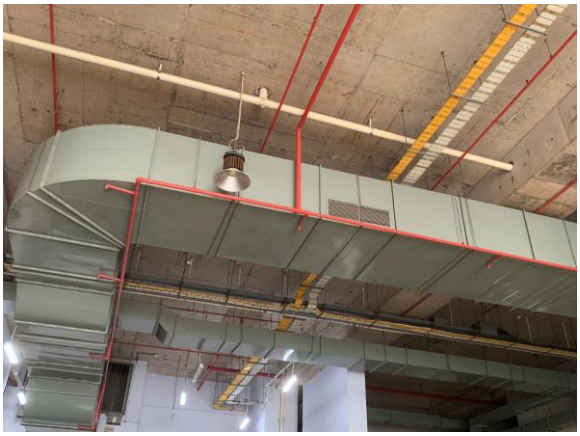


Figure 3-4: ACMV System and Fixtures

3.1 Common Causes of the Collapse of ACMV Fixtures

Lack of maintenance of the ACMV fixture can cause deterioration of the supporting structure, which may result in a partial or full collapse of the ACMV fixture. Examples of collapsed ACMV fixtures are shown in Figure 3-5 and Figure 3-6, and the common causes of collapse are tabulated below.

Figure 3-5: Collapsed ACMV Duct Due to Excessive Condensation

Figure 3-6: Collapsed ACMV Duct Due to Excessive Condensation

COMMON CAUSES OF THE COLLAPSE OF ACMV FIXTURES
1. Inadequate inspections and ineffective maintenance plans (e.g., inspection done on an irregular/prolonged interval or inspection carried out by untrained personnel, etc.) that lead to undetected or unaddressed defects and issues in the ACMV fixture and its supporting structures, such as: a. Accumulation of water due to condensation[9]; b. Corrosion; c. Spalling and crack of the supporting concrete elements[10]; and d. Other forms of wear and tear.

[9] Excessive accumulation of water in the ACMV fixture may occur due to a low set temperature, ineffective thermal insulation of the ducts, lack of vapour barriers for the rockwool layer, and the infiltration of air with high humidity, which may increase the amount of condensation on the ducts.

[10] The fasteners that are used to secure the ACMV fixture or ducts could fail if they are attached to defective or cracked concrete.

2. Inappropriate alteration to the ACMV fixture and its supporting structures, such as: a. Altering or removing the hangers; and b. Inappropriate addition of fixtures or equipment (e.g. suspended ceiling, cabinets, piping works, additional display, signages, etc.) to the ACMV fixtures or their supporting structure such that additional loads are imposed beyond the allowable loads that the fixtures or the supporting structures are designed to carry.
3. Inappropriate use of suspended ceiling spaces beneath the ACMV fixtures, such as crawling on the suspended ceiling during maintenance of ACMV fixtures.
4. Poor workmanship and improper installation of the ACMV fixture.

3.2 Good Practices for the Design and Installation of ACMV Fixtures

The industry should adopt the following good practices when designing and installing ACMV fixtures and their supporting structures to ensure the safety of building users and maintenance personnel.

RECOMMENDATIONS (DESIGN AND INSTALLATION)
1. Conform to established standards[11] for the design, specification, installation and testing of ACMV system and fixture. These standards include: a. Singapore Standard (SS553: 2009 Code of Practise for Air-conditioning and Mechanical Ventilation in Buildings) (formerly CP 13); b. ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) Handbook;

[11] Please refer to the prevailing applicable version of the Codes and Standards.

c. IHVE (Institution of Heating and Ventilating Engineers) Guidebooks; or

d. SMACNA (Sheet Metal and Air Conditioning Contractors' National Association) manuals.

2. Engage a registered Professional Engineer (PE) in the Mechanical Engineering discipline to review the design of the insulation system and the design of its acoustic provisions as a whole to ensure that there is no risk of excessive condensation, which may lead to the accumulation of water in the ducts causing overloading and damage to the ACMV fixtures and their supporting structures.

3. Engage a registered Professional Engineer (PE) in the Civil Engineering discipline to design and supervise the installation of the supporting structure of the system. The design should consider the following:

   a. Loads such as the weight of services and its supporting frames;

   b. Robustness such as provisions for redundancy[12] and consideration of uneven distributed load in a multiple hanging system;

   c. The ACMV fixtures are designed such that the failure or removal of a single hanger or support does not cause progressive collapse of the system;

   d. Capacity of the supporting hangers, brackets and anchors based on the manufacturer's recommendation[13];

   e. SMACNA manuals and ASHRAE handbook recommends to design for a safety factor of 4 to 5 times the working load for the upper attachments (e.g., anchor and upper bracket, end plate, clips) of the hanger supports or in accordance with manufacturer's recommendation[14]; and

[12] Provisions for redundancy to accommodate unexpected additional live loads such as those due to the accumulation of water and displacement of heavy fixtures, etc., could be considered during the design of the supporting structures.
[13] The use of durable and corrosion-resistant material for load bearing components of the ACMV fixture and its supporting structure should be considered.
[14] The use of durable and corrosion-resistant material for load bearing components of the ACMV fixture and its supporting structure should be considered.

f. Design and component choices for ACMV fixtures and their supporting structures installed at the exterior of the building should be suitable for its intended use taking into consideration the influence from the higher wind load and the effect of external weathering.

4. The following should be considered for the anchors, screws and rivets used for installation.

    a. Corrosion resistant material such as stainless-steel of minimum grade SS304 should preferably be used for the anchors, screws and rivets subjected to external weathering or wet conditions. For indoor space with dry condition, the use of galvanised-steel fasteners shall be a minimum requirement;

    b. Design and installation of anchors to conform to BS 8539:2012 - Code[15] of Practice for Selection and Installation of Post-Installed Anchors in Concrete and Masonry;

    c. The required embedment depth for the anchor installation into the reinforced concrete structural elements should extend beyond the concrete cover to the reinforcement layer when measured from the base material, and this required embedment depth should exclude the thickness of any plaster layer;

    d. Anchor used should be suitable for anchoring into concrete (e.g., cracked-approved anchor) to account for microcracks in concrete;

    e. Consult the supplier, manufacturer, or a registered Professional Engineer in the Civil Engineering discipline for the suitable type of anchors, screws and rivets to be used;

    f. Procure anchors, screws and rivets from reliable manufacturers and suppliers;

    g. Adhere to the installation guide provided by the manufacturers;

    h. Attend courses on anchor installation by established course provider; and

[15] Please refer to the prevailing applicable version of the Codes and Standards.

i. Carry out testing of anchors according to BS 8539:2012 and the latest edition of the normative reference published by the Construction Fixings Association Guidance Note – Procedure for Site Testing Construction Fixings.

5. Procure ACMV from reliable manufacturers and suppliers who provide PE design, warranties and maintenance programs for its fixtures and supporting structures (e.g., supports, frames and connections.

6. Engage the supplier, manufacturer, specialist or a registered Professional Engineer in the Civil Engineering discipline to design and supervise any alteration or modification to the ACMV fixtures or their supporting structures.

7. Other design and installation considerations include:

   a. A coordinated services drawing, where all building services are overlaid into one plan, should be prepared prior to installation to avoid obstruction from the various building services during installation;

   b. Ensure hangers are not bent or kinked in an attempt to avoid building services and obstructions during installation;

   c. The use of lightweight ducts or prefabricated mechanical, electrical and plumbing (MEP) system for better quality control;

   d. Professional Engineer (PE) should be notified to provide alternative support system in the event that hangers and other supporting structures cannot be installed according to design due to obstruction by other building services;

   e. The ACMV supporting structures should not be used to support other building fixtures unless specifically designed to do so;

   f. Conduct non-destructive pull-out test at critical locations for heavy fixtures;

g. Ensure easy access to all ACMV equipment and fixtures[16] (e.g., For ACMV equipment installed above ceiling, provide adequate access panels and install ACMV equipment at a height that is reachable from the access panels);

h. Fixing to steel soffit of composite slab should be carried out in accordance with the guidelines and requirements of the specific product;

i. A means to discharge unexpected accumulation of water in the ACMV fixture, which could be due to excessive condensation or leaks; and

j. Ensure condensate pipes are adequately sized with sufficient gradient to discharge condensate water effectively.

3.3 Good Practices for the Inspection and Maintenance of ACMV Fixtures

Poorly maintained and defective ACMV fixtures pose a safety risk to public. Building owners and responsible parties should carry out regular inspections and maintenance of ACMV fixtures and adopt the following good practices.

RECOMMENDATIONS (MAINTENANCE AND INSPECTION)
1. Schedule for regular inspection of the ACMV fixtures and their supporting structures, and keep inspection records for future reference. The following recommendations may be considered: a. Carry out visual inspection on an annual basis and a full inspection at intervals of not more than three years as recommended in BS 8210:2020 Code[17] of Practice for Facilities Maintenance Management or as recommended by the manufacturer, whichever is earlier;

[16] Please refer to the Design for Maintainability (DfM) Guide for more information.
[17] Please refer to the prevailing applicable version of the Codes and Standards.

b. Check validity/expiry of warranty for product and its supporting structures;

c. Maintenance and inspection may be carried out by in-house maintenance team, or by external maintenance firm engaged by the building owners or responsible parties. Building owners or responsible parties may also engage a specialist or a Professional Engineer (PE) in the Civil Engineering discipline to carry out the inspection;

d. Place emphasis on ACMV fixtures over high human traffic areas and high density public assembly areas where members of the public would be present for a substantial length of time (e.g., waiting/seating areas, lobbies, entrance, food courts, etc.);

e. Place emphasis on ACMV fixtures subjected to unfavourable environmental conditions such as exposure to wind, rain, moisture, condensation, exhaust, heat and vibration that may accelerate the deterioration of fixtures;

f. Keep records of any known maintenance problems and previous rectifications carried out on the ACMV fixtures. Useful plans, sketches, photographs and tabulations could also be kept to illustrate the findings of the inspection;

g. Adequately photograph and document details of any new defects (e.g., location, defect observed, repair work that was carried out, etc.);

h. Implement a maintenance plan to identify defects[18] early, conduct a detailed investigation to ascertain the root causes of such defects, and promptly repair the defects;

i. Building owners and responsible parties are recommended to incorporate monitoring and predictive element, such as sensors and artificial intelligence, into their Building Management Systems (BMS) to collect and analyse trends and operating conditions of the critical components in the asset. Parameters that can be monitored

[18] Building owners and responsible parties are advised to promptly investigate and address the root cause of defects especially defects such as spalling concrete, water seepage and excessive accumulation of water.

include changes in ambient temperature and humidity and these can help detect early onset of any condensation of ACMV equipment;

j. Engage the supplier, manufacturer, specialist or a registered Professional Engineer to address any defects that warrant further investigation; and

k. Refer to the SS553 for the maintenance guidelines on ACMV equipment and fixtures.

2. Adhere to the operation and maintenance manual provided by the supplier or manufacturer of the ACMV fixture, which may include the following:

   a. Replacement of deteriorated ACMV ducts and other components;

   b. Replacement of deteriorated or detached anchors with stainless-steel anchors;

   c. Tightening of loose nuts and hangers;

   d. Ensure condensate water are effectively discharged via condensate pipes; and

   e. Consult the supplier, manufacturer, specialist or a registered Professional Engineer in the Civil Engineering discipline for any repair, replacement or alteration to the supporting structure such as anchors and hangers.

3. Promptly inspect and address any maintenance issues reported by tenants or members of the public, such as water leaks from the roof, plumbing or ACMV fixtures.

3.4 Inspection Guidelines for ACMV Fixtures

Building owners and responsible parties should be vigilant and look out for any of the following warning signs of damage and deterioration of the ACMV fixtures, supporting structures and the structural elements to which they are installed.

SIGNS OF DAMAGE OR DETERIORATION

1. Inspection should be carried based on approved drawings, manufacturer's guide and product manual. Thorough inspection should be carried out, especially at areas of major concern such as public area, high traffic area and weather prone area.

2. Building owners and responsible parties should look out for the following signs when inspecting the ACMV fixtures and components.

    a. Sagging, deformed or uneven ACMV components which may lead to dislodgement;

    b. Excessive condensation or accumulation of water which may lead to overloading on fixtures and components;

    c. Presence of water stains, efflorescence and moulds which may lead to corrosion of ACMV fixtures and components;

    d. Dislodged ACMV fixtures or components, which may impose additional loads on the system;

    e. Choked condensate pipe which prevents condensate water from being discharged effectively; and

    f. Review the analytical and predictive data in the Building Management Systems (BMS) to identify defects in the operation and condition of the ACMV equipment and its components. Data includes leakages, temperature and humidity fluctuation, excessive vibration, etc.

3. Building owners and responsible parties should look out for the following signs when inspecting the **supporting structures** of the ACMV fixtures.

    a. Missing, sagging, deformed, bent, loose or otherwise damaged supporting structures of the ACMV fixture such as anchors, connectors, and hangers;

    b. Inappropriate alteration or removal of the supporting structure, such as hangers, frames and bolts and nuts;

    c. Signs of corrosion or rust on the supporting structures; and

d. Additional fixtures such as lighting, piping, ducts and diffusers that do not have an independent support and are imposing additional loads on the supporting structures of the ACMV fixture.

4. Building owners and responsible parties should look out for the following signs when inspecting the **structural elements** to which the ACMV fixtures are installed such as columns, beams and slab.

    a. Concrete crack lines;

    b. Spalling concrete;

    c. Corrosion;

    d. Water stains or water seepage;

    e. Termite infestation; and

    f. Other signs of deterioration.

5. Should there be any defects observed, building owners and responsible parties are advised to contact the supplier, manufacturer, specialist or a registered Professional Engineer for advice and repair/replacement.

3.5 AIR-CONDITIONING AND MECHANICAL VENTILATION (ACMV) FIXTURES INSTALLATION CHECKLIST

Building: Company:

Block / Storey: Name of Installer:

Date of Installation: Name of Supervisor:

S/N	Description	✓/×/NA	Remarks
1.0	**ACMV Installation**		
1.1	Approved shop drawing endorsed by a Professional Engineer (PE) and coordinated services drawing is submitted and available on installation site		
1.2	Mark out locations of fixing points prior to installation to ensure the fixing points are positioned well within the available supporting structure		
1.3	Hangers are not to be bent or kinked in an attempt to avoid building services and obstructions during installation		
1.4	Professional Engineer (PE) is notified to provide alternative support system when hangers cannot be installed according to design due to obstruction by other building services		
1.5	The ACMV system is not used to support other building fixtures and vice versa unless specifically designed to do so		
1.6	Fixing to steel soffit of composite slab is carried out in accordance with the approved drawings and the requirements of the specific product		
1.7	Ensure condensate pipes are adequately sized with sufficient gradient to discharge condensate water effectively		

1.8	Easy access to all ACMV equipment and fixtures[19] (e.g., for ACMV equipment installed above ceiling, to provide adequate access panels and install ACMV equipment at a height that is reachable from the access panels)		
2.0	**Connections and Anchors**		
2.1	Anchors, screws and rivets are made of corrosion resistant material; preferably made of stainless-steel with minimum grade SS304 when used in area subjected to external weathering or wet condition, and minimally made of galvanised-steel when used in indoor space with dry condition		
2.2	The required embedment depth of anchors should extend beyond the concrete cover and exclude the thickness of any plaster layer		
2.3	Suitable type of anchors are used in accordance to the approved drawings as prescribed by the Professional Engineer		
2.4	Anchors, screws and rivets are procured from reliable manufacturers or suppliers and installed in accordance with the manufacturer's installation guidelines		
2.5	Anchor installer is well trained and has attended courses on anchor installation by established course provider		

[19] Please refer to the Design for Maintainability (DfM) Guide for more information.

3.6 AIR-CONDITIONING AND MECHANICAL VENTILATION (ACMV) FIXTURES MAINTENANCE AND INSPECTION CHECKLIST

Building: Company:

Block / Storey: Name of Supervisor:

Inspection frequency: Date of Inspection:

S/N	Description	✓/×/NA	Remarks
1.0	**Documentation**		
1.1	A set of approved drawings, manufacturer/supplier's operation and maintenance manual (OEM) and warranty documentation are available		
1.2	Review records of any known maintenance problems and previous rectifications carried out on the fixtures, including data from the Building Management Systems (BMS) such as leakages, temperature and humidity fluctuation, excessive vibration, etc.		
1.3	Place emphasis on ACMV fixtures over high human traffic and public assembly areas such as waiting/seating areas, lobbies, entrance, food courts, etc.		
1.4	Place emphasis on ACMV fixtures subjected to unfavourable environmental conditions such as exposure to wind, rain, moisture, condensation, exhaust, heat and vibration that may accelerate the deterioration of fixtures		
1.5	Photograph and document details of any new defects and repair work (e.g., location, defect observed, repair work that was carried out, etc.)		
2.0	**ACMV Fixtures and Components**		
2.1	No sagging, deformed, damaged or dislodged suspended ACMV fixtures and components		
2.2	No insulation/joint damage, excessive condensation or accumulation of water on ACMV components		

2.3	No water stains, efflorescence, or moulds		
2.4	No fixture or equipment such as suspended ceiling, lighting, piping, ducts, and diffusers is dislodged and imposing its self-weight onto the suspended ACMV components or frame		
2.5	No choked condensate pipe which prevents condensate water from being discharged effectively		
3	**Supporting Structures – Hangers, Frames, And Connections**		
3.1	No missing, loose, bent, kinked, corroded, sagging, damaged or inappropriately altered supporting structures such as hangers, frames, bolts, nuts, screws, clips, brackets, etc.		
3.2	No hanger is used to support other building fixtures not designed for (e.g., cabinets, pipes, display screens, signages, etc.)		
3.3	No signs of other forms of deterioration and damage on the hangers, frames and connecting bolts and nuts		
4.0	**Structural Elements – Columns, Beams, And Slab**		
4.1	No concrete crack lines around the connections		
4.2	No spalling concrete		
4.3	No corrosion on steel structure		
4.4	No water stains or water seepage		
4.5	No termite infestation		
4.6	No other signs of deterioration		

Note:

Should there be any defects observed, building owners and responsible parties are advised to contact the supplier, manufacturer, specialist or a registered Professional Engineer for advice and repair/replacement.

4 MECHANICAL, ELECTRICAL AND PLUMBING (MEP) FIXTURES

Mechanical, Electrical and Plumbing (MEP) system forms the central nervous system in the operation of a building. MEP systems such as water pipes, electrical wiring on cable trays, kitchen exhaust ducts and fire sprinkler system make buildings habitable and ensure the comfort of people living within. These MEP systems are supported by hangers and brackets and normally run overhead suspended on the ceiling and hence failure of the supporting system poses a danger to the public accessing the space below.

This chapter explains the common causes of the dislodgement of MEP fixtures and recommends good practices for the design, installation and maintenance of MEP fixtures.

Examples of MEP fixtures are shown in Figure 4-1 to Figure 4-4.

Figure 4-1: MEP System and Fixtures

Figure 4-2: Aircon Compressor and Fixtures

Figure 4-3: MEP System and Fixtures

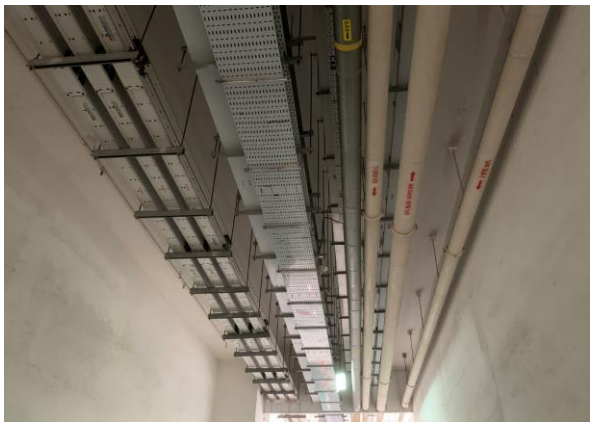


Figure 4-4: MEP System and Fixtures

4.1 Common Causes of the Dislodgement of MEP Fixtures

Lack of maintenance and improper use of MEP fixtures and their supporting structures would cause them to deteriorate and result in partial or full dislodgements. Examples of dislodged MEP fixtures are shown in Figure 4-5 and Figure 4-6, and the common causes of collapse are tabulated below.

Figure 4-5: Dislodged Water Pipe fixtures

Figure 4-6: Corroded Aircon Compressor Fixture

COMMON CAUSES OF THE DISLODGEMENT OF MEP FIXTURES
1. Inadequate inspections and ineffective maintenance plans (e.g., inspection done on an irregular/prolonged interval or inspection carried out by untrained personnel, etc.) that lead to undetected or unaddressed defects and issues in the MEP system, such as: a. Corrosion; b. Spalling and crack of supporting concrete elements; c. Mechanical and termination joints not properly installed and secured, causing water seepages and equipment to dislodge; and d. Other forms of wear and tear.

2. Inappropriate alteration to the MEP fixtures and their supporting structures, such as:

    a. Altering or removing the hangers; and

    b. Inappropriate addition of fixtures or equipment (e.g. suspended ceiling, cabinets, piping works, additional display, signages, etc.) to the MEP fixtures or their supporting structures such that additional loads are imposed beyond the allowable loads that the fixtures or the supporting structures are designed to carry.

3. Poor workmanship and improper installation of MEP system and its fixtures.

4.2 Good Practice for the Design and Installation of MEP Fixtures

The industry should adopt the following good practices when designing and installing MEP fixtures and their supporting structures to ensure the safety of building users and maintenance personnel.

RECOMMENDATIONS (DESIGN AND INSTALLATION)
1. Conform to established standards[20] for design, specification, installation and testing of MEP fixtures. These standards include: a. Manufacturers Standardization Society (MMS SP-58-2018, Pipe Hangers and Supports – Materials, Design, Manufacture, Selection, Application, and Installation); b. Singapore Standard (SS 636:2018 Code of Practice for Water Services – Installation requirements on fixing (Formerly CP 48); c. Singapore Standard (SS CP 52:2004 Code of Practice for Automatic Fire Sprinkler System – Design, Specification, Installation and Testing Requirements on Fixing); and

[20] Please refer to the prevailing applicable version of the Codes and Standards.

d. Singapore Standard (SS 608:2015+A1:2017 Code of Practice for Gas Installation – Design and Installation Requirements on Fixing) (Formerly CP 51).

2. Engage a registered Professional Engineer in the Civil Engineering discipline to design and supervise the installation of the supporting structure of the system. The design should consider the following:

    a. Loads such as the weight of services and their supporting frames;

    b. Robustness such as provisions for redundancy[21] and consideration of uneven distributed load in a multiple hanging system;

    c. The MEP fixtures are designed such that the failure or removal of a single hanger or support does not cause progressive collapse of the system;

    d. Capacity of the supporting hangers, brackets and anchors based on the manufacturer's recommendation[22];

    e. Design and component choices for MEP fixtures and their supporting structures installed at the exterior of the building should be suitable for their intended use taking into consideration the influence from the higher wind load and the effect of external weathering;

    f. SS CP 52:2004 indicates the sprinkler pipe support and fixing to be designed to support two times the mass of the piping filled with water plus a load of 115kg at each point of support;

    g. SS 608:2015+A1:2017 indicates the gas pipe supporting bracket to have a maximum spacing not exceeding 3 metre;

[21] Provisions for redundancy to accommodate unexpected additional live loads such as those due to the accumulation of water and displacement of heavy fixtures, etc., could be considered during the design of the supporting structures.

[22] The use of durable and corrosion-resistant material for load bearing components of the MEP fixture and its supporting structure should be considered.

h. MMS SP-58-2018 recommends to design for a safety factor of 4 to 5 times the working load for pipe hangers and supports (e.g., anchor and upper bracket, end plate, clips), or in accordance with manufacturer's recommendation; and

i. SS 636:2018 provides the requirement for the spacing of fixings for internal water piping as shown in Table 4-1.

Type of piping	Size of pipe in mm	Spacing for horizontal runs in m	Spacing for vertical runs in m
Rigid plastic	< 32	1.0	1.5
	40 – 80	1.25	2.0
	100 – 150	1.5	3.0
Copper (light gauge) stainless steel	< 32	1.5	2.0
	40 – 80	2.5	3.0
	100 – 150	3.0	3.5
Copper (heavy gauge)	< 32	2.0	2.5
	40 – 180	3.0	3.5
	100 – 150	4.0	4.5
Ductile iron	75 – 100	2.5	2.5
	150	3.5	3.5

Table 4-1 Spacing of Fixings for Water Piping
(This table 4-1 is adapted from SS 636:2018. Copyright by Enterprise Singapore 2018)

3. The following should be considered for the anchors, screws and rivets used for installation.

   a. Corrosion resistant material such as stainless-steel of minimum grade SS304 should preferably be used for the anchors, screws and rivets subjected to external weathering or wet conditions. For indoor space with dry condition, the use of galvanised-steel fasteners shall be a minimum requirement;

   b. Design and installation of anchors to conform to BS 8539:2012 - Code[23] of Practice for Selection and Installation of Post-Installed Anchors in Concrete and Masonry;

   c. The required embedment depth for the anchor installation into the reinforced concrete structural elements should extend beyond the concrete cover to the reinforcement layer when

[23] Please refer to the prevailing applicable version of the Codes and Standards.

measured from the base material, and this required embedment depth should exclude the thickness of any plaster layer;

d. Anchor used should be suitable for anchoring into concrete (e.g., cracked-approved anchor) to account for microcracks in concrete;

e. Consult the supplier, manufacturer, or a registered Professional Engineer in the Civil Engineering discipline for the suitable type of anchors, screws and rivets to be used;

f. Procure anchors, screws and rivets from reliable manufacturers and suppliers;

g. Adhere to the installation guide provided by the manufacturers;

h. Attend courses on anchor installation by established course provider; and

i. Carry out testing of anchors according to BS 8539:2012 and the latest edition of the normative reference published by the Construction Fixings Association Guidance Note – Procedure for Site Testing Construction Fixings.

4. Procure MEP fixtures and components (e.g., supports, frames and connections) from reliable manufacturers and suppliers who provide warranty and maintenance support.

5. Engage the supplier, manufacturer, specialist or a registered Professional Engineer in the Civil Engineering discipline to design and supervise any alteration or modification to the MEP fixtures or their supporting structures.

6. Other design and installation considerations include:

a. A coordinated services drawing, where all building services are overlaid into one plan, should be prepared prior to installation to avoid obstruction from the various building services during installation;

b. Ensure hangers are not bent or kinked in an attempt to avoid building services and obstructions during installation;

c. The use of lightweight ducts or prefabricated mechanical, electrical and plumbing (MEP) system for better quality control;

d. Supplier, manufacturer or specialist and Professional Engineer (PE) should be notified to provide alternative support system in the event that hangers and other supporting structures cannot be installed according to design due to obstruction by other building services;

e. The MEP fixtures should not be used to support other building fixtures and vice versa unless specifically designed to do so;

f. Conduct non-destructive pull-out test at critical locations for heavy fixtures;

g. Ensure easy access to all MEP equipment and fixtures[24] (e.g., adequate access panels for concealed services;

h. A means to discharge unexpected accumulation of water in the MEP fixture, which could be due to excessive condensation or leaks;

i. Fixing to steel soffit of composite slab should be carried out in accordance with the guidelines and requirements of the specific product; and

j. locations of fixing points prior to installation to ensure the fixing points are positioned well within the available supporting structure.

4.3 Good Practices for the Inspection and Maintenance of MEP Fixtures

Poorly maintained and defective MEP fixtures pose a risk to public safety. Building owners and responsible parties should carry out regular inspections and maintenance of MEP fixtures and adopt the following good practices.

[24] Please refer to the Design for Maintainability (DfM) Guide for more information.

RECOMMENDATIONS (MAINTENANCE AND INSPECTION)

1. Schedule for regular inspection of the MEP fixtures and their supporting structures, and keep inspection records for future reference. The following recommendations may be considered:

    a. Carry out visual inspection on an annual basis and a full inspection at intervals of not more than three years as recommended in BS 8210:2020 Code[25] of Practice for Facilities Maintenance Management or as recommended by the manufacturer, whichever is earlier;

    b. Check validity/expiry of warranty for product and its supporting structures;

    c. Maintenance and inspection may be carried out by in-house maintenance team, or by external maintenance firm engaged by the building owners or responsible parties. Building owners or responsible parties may also engage a specialist or a Professional Engineer (PE) in the Civil Engineering discipline to carry out the inspection;

    d. Place emphasis on MEP fixtures over high human traffic areas and high density public assembly areas where members of the public would be present for a substantial length of time (e.g., waiting/seating areas, lobbies, entrance, food courts, etc.);

    e. Place emphasis on MEP fixtures subjected to unfavourable environmental conditions such as exposure to wind, rain, moisture, condensation, exhaust, heat and vibration that may accelerate the deterioration of fixtures;

    f. Keep records of any known maintenance problems and previous rectifications carried out on the MEP fixtures. Useful plans, sketches, photographs and tabulations could also be kept to illustrate the findings of the inspection;

[25] Please refer to the prevailing applicable version of the Codes and Standards.

g. Adequately photograph and document details of any new defects (e.g., location, defect observed, repair work that was carried out, etc.);

h. Implement a maintenance plan to identify defects[26] early, conduct a detailed investigation to ascertain the root causes of such defects, and promptly repair the defects;

i. Building owners and responsible parties are recommended to incorporate monitoring and predictive element, such as sensors and artificial intelligence, into their Building Management Systems (BMS) to collect and analyse trends and operating conditions of the MEP system and its components. Parameters that may be monitored include leakages, excessive vibration, etc.; and

j. Engage the supplier, manufacturer, specialist or a registered Professional Engineer to address any defects that warrant further investigation.

2. Adhere to the operation and maintenance manual provided by the supplier or manufacturer of the MEP fixture, which may include the following:

   a. Replacement of deteriorated MEP components;

   b. Replacement of deteriorated or detached anchors with stainless-steel anchors;

   c. Tightening of loose nuts and hangers; and

   d. Consult the supplier, manufacturer, specialist or a registered Professional Engineer in the Civil Engineering discipline for any repair, replacement or alteration to the supporting structure such as anchors and hangers.

3. Promptly inspect and address any maintenance issues reported by tenants or members of the public, such as water leaks, pipe burst, dangling metal trays/hangers, etc.

[26] Building owners and responsible parties are advised to promptly investigate and address the root cause of defects especially defects such as spalling concrete, water seepage and excessive accumulation of water.

4.4 Inspection Guidelines for MEP Fixtures

Building owners and responsible parties should be vigilant and look out for any of the following warning signs of damage and deterioration of the MEP fixtures, supporting structures and the structural elements to which they are installed.

SIGNS OF DAMAGE OR DETERIORATION
1. Inspection should be carried based on approved drawings, manufacturer's guide and product manual. Thorough inspection should be carried out, especially at areas of major concern such as public area, high traffic area and weather prone area.
2. Building owners and responsible parties should look out for the following signs when inspecting the MEP fixtures and components. a. Sagging, deformed or uneven MEP system components or dislodgement of any of the MEP system or components; b. Presence of excessive condensation, water stains, efflorescence or moulds which may lead to corrosion of MEP fixtures and components; c. Dislodged MEP fixtures or components, which may impose additional loads on the system; and d. Review the analytical and predictive data in the Building Management Systems (BMS) to identify defects in the operation and condition of the MEP equipment and its components. Data includes leakages, excessive vibration, etc.
3. Building owners and responsible parties should look out for the following signs when inspecting the **supporting structures** of the MEP fixtures. a. Missing, sagging, deformed, bent, loose or otherwise damaged supporting structures of the MEP fixture such as anchors, connectors and hangers; b. Inappropriate alteration or removal of the supporting structure, such as hangers, frames and bolts and nuts;

c. Signs of corrosion or rust on the supporting structures; and

d. Additional fixtures such as lighting, cabinets, display screen that do not have an independent support and are imposing additional loads on the supporting structures of the MEP fixture.

4. Building owners and responsible parties should look out for the following signs when inspecting the **structural elements** to which the MEP fixtures are installed such as columns, beams and slab.

   a. Concrete crack lines;

   b. Spalling concrete;

   c. Corrosion;

   d. Water stains or water seepage;

   e. Termite infestation; and

   f. Other signs of deterioration.

5. Should there be any defects observed, building owners and responsible parties are advised to contact the supplier, manufacturer, specialist or a registered Professional Engineer for advice and repair/replacement.

4.5 MECHANICAL, ELECTRICAL AND PLUMBING (MEP) FIXTURES INSTALLATION CHECKLIST

Building: Company:

Block / Storey: Name of Installer:

Date of Installation: Name of Supervisor:

S/N	Description	✓/×/NA	Remarks
1.0	**MEP Installation**		
1.1	Approved shop drawing endorsed by a Professional Engineer (PE) and coordinated services drawing is submitted and available on installation site		
1.2	Mark out locations of fixing points prior to installation to ensure the fixing points are positioned well within the available supporting structure		
1.3	Hangers are not to be bent or kinked in an attempt to avoid building services and obstructions during installation		
1.4	Secondary members are installed according to design when hangers are obstructed by building services		
1.5	The MEP system is not used to support other building fixtures and vice versa unless specifically designed to do so		
1.6	A means to discharge unexpected accumulation of water in the MEP fixture, which could be due to excessive condensation or leaks, are provided		
1.7	Ensure easy access to all MEP equipment and fixtures[27] (e.g., adequate access panels for concealed services)		

[27] Please refer to the Design for Maintainability (DfM) Guide for more information.

1.8	Fixing to steel soffit of composite slab is carried out in accordance with the approved drawings and the requirements of the specific product		
1.9	Mechanical and termination joints are properly installed and secured, to prevent causing water seepages and equipment to dislodge		
2.0	**Connections and Anchors**		
2.1	Anchors, screws and rivets are made of corrosion resistant material; preferably made of stainless-steel with minimum grade SS304 when used in area subjected to external weathering or wet condition, and minimally made of galvanised-steel when used in indoor space with dry condition		
2.2	The required embedment depth of anchors should extend beyond the concrete cover and exclude the thickness of any plaster layer		
2.3	Suitable type of anchors are used in accordance to the approved drawings as prescribed by the Professional Engineer		
2.4	Anchors, screws and rivets are procured from reliable manufacturers or suppliers and installed in accordance with the manufacturer's installation guidelines		
2.5	Anchor installer is well trained and has attend courses on anchor installation by established course provider		

4.6 MECHANICAL, ELECTRICAL AND PLUMBING (MEP) FIXTURES MAINTENANCE AND INSPECTION CHECKLIST

Building: Company:

Block / Storey: Name of Supervisor:

Inspection frequency: Date of Inspection:

S/N	Description	✓/×/NA	Remarks
1.0	**Documentation**		
1.1	A set of approved drawings, manufacturer/supplier's operation and maintenance manual (OEM) and warranty documentation are available		
1.2	Review records of any known maintenance problems and previous rectifications carried out on the fixtures, including data from the Building Management Systems (BMS) such as leakages, excessive vibration, etc.		
1.3	Place emphasis on MEP fixtures over high human traffic and public assembly areas such as waiting/seating areas, lobbies, entrance, food courts, etc.		
1.4	Place emphasis on MEP fixtures subjected to unfavourable environmental conditions such as exposure to wind, rain, moisture, condensation, exhaust, heat and vibration that may accelerate the deterioration of fixtures		
1.5	Photograph and document details of any new defects (e.g., location, defect observed, repair work that was carried out, etc.)		
2.0	**MEP Fixtures and Components**		
2.1	No sagging, deformed, damaged or dislodged suspended MEP fixtures and components		
2.2	No loose mechanical and termination joints causing water seepages and equipment to dislodge		

2.3	No excessive condensation or accumulation of water on MEP components		
2.4	No water stains, efflorescence, or moulds		
2.5	No fixture or equipment such as lighting, piping, ducts, and diffusers is dislodged and imposing its self-weight onto the suspended MEP components or frame		
3.0	**Supporting Structures – Hangers, Frames, And Connections**		
3.1	No missing, loose, bent, kinked, corroded, sagging, damaged or inappropriately altered supporting structures such as hangers, frames, bolts, nuts, screws, clips, brackets, etc.		
3.2	No hanger is used to support other building fixtures not designed for (e.g., cabinets, pipes, display screens, signages, etc.)		
3.3	No signs of other forms of deterioration and damage on the hangers, frames and connecting bolts and nuts		
4.0	**Structural Elements – Columns, Beams, And Slab**		
4.1	No concrete crack lines around the connections		
4.2	No spalling concrete		
4.3	No corrosion on steel structure		
4.4	No water stains or water seepage		
4.5	No termite infestation		
4.6	No other signs of deterioration		

Note:

Should there be any defects observed, building owners and responsible parties are advised to contact the supplier, manufacturer, specialist or a registered Professional Engineer for advice and repair/replacement.

5 HIGH VOLUME LOW SPEED (HVLS) FANS

High volume low speed fans are overhead fans having blade span of up to 8 metres to provide general cooling over a large area of space. As these fans have large span and weigh up to 200 kilograms, any incident involving dislodgement of the HVLS fan or its supporting structures could pose a safety risk to the public. Therefore, utmost care should be taken in terms of the design, installation, and maintenance of HVLS fans and their supporting structures.

This chapter advises the industry on good practices for the design, installation and maintenance of HVLS fans and their supporting structures. More emphasis to be given to HVLS fans installed in public spaces and venues such as hawker centres, shopping centres, sports hall, MRT stations, convention centres and industrial buildings.

Figure 5-1 to Figure 5-4 provides some examples of HVLS fans.

Figure 5-1: HVLS Fan in Shopping Mall

Figure 5-2: HVLS Fan attached to steel structure

Figure 5-3: HVLS Fan in Public Spaces

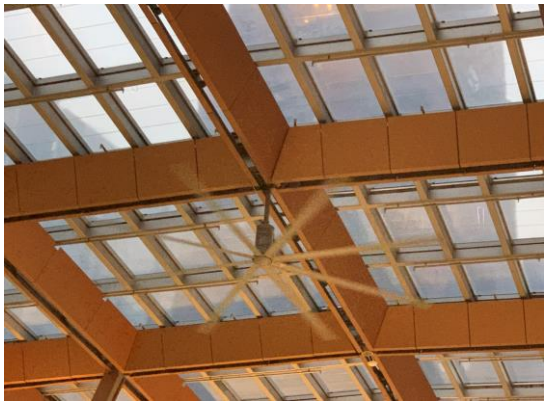


Figure 5-4: HVLS Fan Attached to Steel Structure

5.1 Possible Causes of the Dislodgement of High Volume Low Speed (HVLS) Fan

Lack of maintenance and improper use of HVLS fans can cause the equipment and their supporting structure to deteriorate and result in partial or full dislodgement. The possible causes of the dislodgement of HVLS fan are as follows:

POSSIBLE CAUSES OF DISLODGEMENT OF HVLS FAN
1. Inadequate inspections and ineffective maintenance plans (e.g., inspection done on an irregular/prolonged interval or inspection carried out by untrained personnel, etc.) that lead to undetected or unaddressed defects and issues in the fan, such as: a. Corrosion of the fixtures and its supporting frame; b. Missing bolts and nuts and loose parts; c. Spalling and crack of the supporting concrete elements such a concrete ceiling and beams; and d. Other forms of wear and tear.
2. Installation of fan to structures incapable of supporting the weight of the fan.
3. Inappropriate alteration or removal of the supporting structures and connections, such as safety cables, guy wires and bolts and nuts, of the fan.
4. Inappropriate addition of fixtures or equipment (e.g., suspended ceiling, piping works, additional display, signages, etc.) to the supporting structure such that additional loads are imposed beyond the allowable loads that the supporting structures are designed to carry.
5. Fan installed too low to the ground or too close to other building fixtures thereby increasing the risk of the fan aerofoil hitting other fixtures or objects.

6. Installation not carried out according to the manufacturer's guide and recommendations.
7. Poor workmanship and improper installation of the fan.

5.2 Good Practices for the Design and Installation of High Volume Low Speed (HVLS) Fan

The industry should adopt the following good practices when designing and installing HVLS fans and the supporting structures to ensure the safety of building users and maintenance personnel.

RECOMMENDATIONS (DESIGN AND INSTALLATION)
1. Conform to established standards[28] for the testing, installation and safety of HVLS fan. The fan product must include the Certificate of Conformity (COC) tested to: a. International Electrotechnical Commission (IEC 60335-2-80: 2015 Household and Similar Electrical Appliances – Safety – Part 2-80: Particular Requirements for Fans), and to sub-clauses 5.7 and 5.8 of SS 360: 1992 or Annex ZA of SS 655: 2020; or b. Singapore Standard (SS655: 2020 Safety of household and similar electrical appliances – Particular Requirements for Fans); and c. Figure 5-5 below from the Consumer Protection (Safety Requirements) Regulations Information Booklet shows the minimum requirement for the support connection details of a HVLS fan mounted onto a concrete ceiling.

[28] Please refer to the prevailing applicable version of the Codes and Standards.

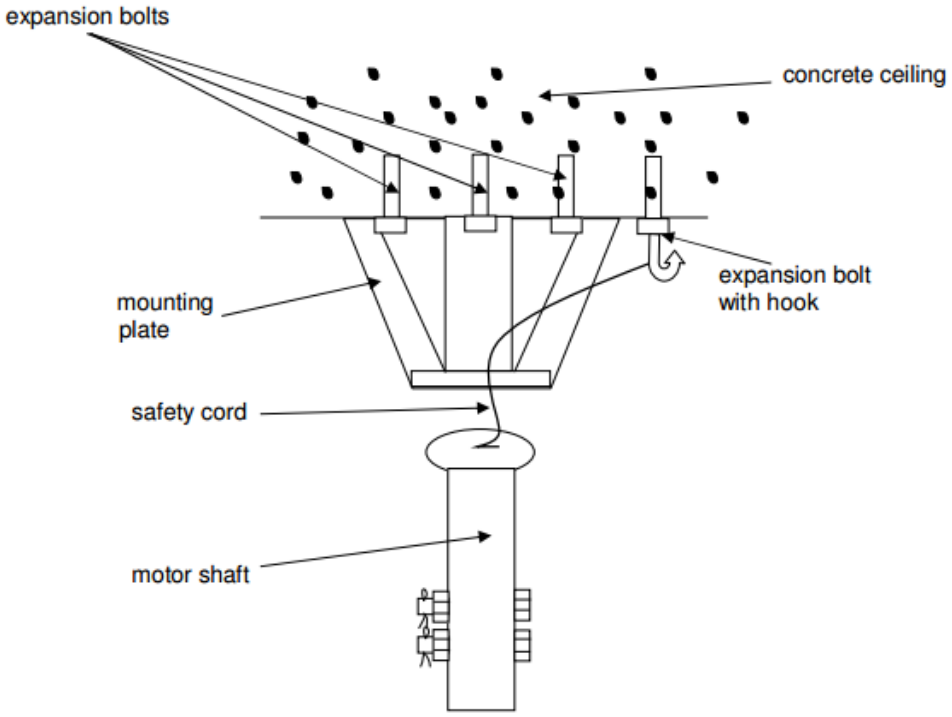


Figure 5-5: Showing The 3 Expansion Bolts, Safety Cord, Expansion Bolts with Hook and Mounting Plate of Ceiling Fan
[This Figure 5-5 is adapted from the Consumer Protection (Safety Requirements) Regulations Information Booklet. Copyright by Enterprise Singapore 2021]

Note: Fan product must carry the 'Safety Mark' as shown in Figure 5-6 below, before they can be sold and installed. Below the logo is a unique certification number traceable to the registrant.

SAFETY MARK
123456-00

Figure 5-6: 'Safety Mark' Logo
[This Figure 5-6 is adapted from the Consumer Protection (Safety Requirements) Regulations Information Booklet. Copyright by Enterprise Singapore 2021]

2. Engage a registered Professional Engineer (PE) in the Civil Engineering discipline to design and supervise the installation of the mounting structures of the fan to the supporting structure of the building. The design should consider the following:

    a. The mounting structures and supporting structures should consider loadings such as weight of the fan, its supporting frames, the additional torque forces generated by the fan during its operation,

and any other condition stated in the manufacturer's recommendation;

b. The mounting structures and supporting structures should consider robustness such as provisions for redundancy through guy wires or safety cables and consideration of uneven distributed load and torque during its operation;

c. The components and supporting structures used for the fan are made of durable and corrosion resistant material;

d. The capacity of the supporting brackets and anchors should be based on manufacturer's recommendations; and

e. Conduct non-destructive pull-out test at critical locations such as at concrete ceiling.

3. The following should be considered for the anchors, screws and rivets used for installation.

   a. Corrosion resistant material such as stainless-steel of minimum grade SS304 should preferably be used for the anchors, screws and rivets subjected to external weathering or wet conditions. For indoor space with dry condition, the use of galvanised-steel fasteners shall be a minimum requirement;

   b. Design and installation of anchors to conform to BS 8539:2012 - Code[29] of Practice for Selection and Installation of Post-Installed Anchors in Concrete and Masonry;

   c. The required embedment depth for the anchor installation into the reinforced concrete structural elements should extend beyond the concrete cover to the reinforcement layer when measured from the base material, and this required embedment depth should exclude the thickness of any plaster layer;

   d. Anchor used should be suitable for anchoring into concrete (e.g., cracked-approved anchor) to account for microcracks in concrete;

[29] Please refer to the prevailing applicable version of the Codes and Standards.

e. Consult the supplier, manufacturer, or a registered Professional Engineer in the Civil Engineering discipline for the suitable type of anchors, screws and rivets to be used;

f. Procure anchors, screws and rivets from reliable manufacturers and suppliers;

g. Adhere to the installation guide provided by the manufacturers;

h. Attend courses on anchor installation by established course provider; and

i. Carry out testing of anchors according to BS 8539:2012 and the latest edition of the normative reference published by the Construction Fixings Association Guidance Note – Procedure for Site Testing Construction Fixings.

4. The following should be considered during the installation of HVLS fan:

a. Installation should be carried out according to the manufacturer's guide and recommendations;

b. Installation should be carried out by an installer familiar with the installation requirements of the product;

c. Ensure the fan is secured with safety cables as a safety measure according to the manufacturer's recommendation and specification;

d. Ensure the fan aerofoil is secured with safety retainer device as a safety measure according to the manufacturer's recommendation and specification, to prevent aerofoil from detaching from the fan body;

e. Ensure the fan has safety mechanism to stop operating automatically upon impact or malfunction;

f. Fan should be installed in accordance to manufacturer's guidelines and not installed too low to the ground or too close to other building fixtures thereby increasing the risk of the fan aerofoil hitting other fixtures or objects;

g. The supporting structure of the fan should not be used to support other building fixtures and vice versa;

h. Verify the mounting location and that the supporting structure can support the weight of the heavy fixtures as per the Professional Engineer (PE) design;

i. Mark out locations of fixing points prior to installation to ensure the fixing points are positioned well within the available supporting structure;

j. Fixing to steel soffit of composite slab should be carried out in accordance with the guidelines and requirements of the specific product; and

k. Provision of access for maintenance[30] to facilitate efficient and effective maintenance to be carried (e.g., sufficient floor space or area to facilitate the machinery or ladder to reach the HVLS fan fixtures at high ceiling and adequate access panels for its concealed fixture support).

5. Procure fan with competent components and connection system from reliable manufacturers and suppliers who provide warranty / maintenance support.

5.3 Good Practices for the Inspection and Maintenance of High Volume Low Speed (HVLS) Fan

Poorly maintained and defective HVLS fans pose a safety risk to the public. Building owners and responsible parties should carry out regular inspections and maintenance of HVLS fans and adopt the following good practices.

RECOMMENDATIONS (MAINTENANCE AND INSPECTION)
1. Schedule for regular inspection of the HVLS fan fixtures and their supporting structures, and keep inspection records for future reference. The following recommendations may be considered:

[30] Please refer to the Design for Maintainability (DfM) Guide for more information.

a. Carry out visual inspection on an annual basis and a full inspection at intervals of not more than three years as recommended in BS 8210:2020 Code[31] of Practice for Facilities Maintenance Management or as recommended by the manufacturer, whichever is earlier;

b. Check validity/expiry of warranty for product and its supporting structures;

c. Maintenance and inspection may be carried out by in-house maintenance team, or by external maintenance firm engaged by the building owners or responsible parties. Building owners or responsible parties may also engage a specialist or a Professional Engineer (PE) in the Civil Engineering discipline to carry out the inspection;

d. Place emphasis on HVLS fan fixtures over high human traffic areas and high density public assembly areas where members of the public would be present for a substantial length of time (e.g., waiting/seating areas, lobbies, entrance, food courts, etc.);

e. Place emphasis on HVLS fan fixtures subjected to unfavourable environmental conditions such as exposure to wind, rain, moisture, condensation, exhaust, heat and vibration that may accelerate the deterioration of fixtures;

f. Keep records of any known maintenance problems and previous rectifications carried out on the HVLS fan fixtures. Useful plans, sketches, photographs and tabulations could also be kept to illustrate the findings of the inspection;

g. Adequately photograph and document details of any new defects (e.g., location, defect observed, repair work that was carried out, etc.);

[31] Please refer to the prevailing applicable version of the Codes and Standards.

h. Implement a maintenance plan to identify defects[32] early, conduct a detailed investigation to ascertain the root causes of such defects, and promptly repair the defects;

i. Building owners and responsible parties are recommended to incorporate monitoring and predictive element, such as sensors and artificial intelligence, into their Building Management Systems (BMS) to collect and analyse trends and operating conditions of the HVLS fan and its components. Parameters that may be monitored include excessive vibration, irregular oscillation, etc.; and

j. Engage the supplier, manufacturer, specialist or a registered Professional Engineer to address any defects that warrant further investigation.

2. Adhere to the operation and maintenance manual provided by the supplier or manufacturer of the HVLS fan, which may include the following:

   a. Replacement of deteriorated fan parts and components such as bolts and nuts, brackets, guy wires and safety cables;

   b. Tightening of loose nuts and cables; and

   c. Consult the supplier, manufacturer, specialist or a registered Professional Engineer in the Civil Engineering discipline for any repair, replacement or alteration to the supporting structure.

3. Promptly inspect and address any maintenance issues reported by tenants or members of the public, such as detached/loose components, wobbling motion of the fan during its operation, slanted aerofoil, etc.

[32] Building owners and responsible parties are advised to promptly investigate and address the root cause of defects especially defects such as spalling concrete, water seepage and excessive accumulation of water.

5.4 Inspection Guidelines for High Volume Low Speed (HVLS) Fan

Building owners and responsible parties should be vigilant and look out for any of the following warning signs of damage and deterioration of the HVLS fan, its supporting structures and the structural elements to which they are installed.

SIGNS OF DAMAGE OR DETERIORATION
1. Inspection should be carried based on approved drawings, manufacturer's guide and product manual. Thorough inspection should be carried out, especially at areas of major concern such as public area, high traffic area and weather prone area.
2. Building owners and responsible parties should look out for the following signs when inspecting the HVLS fan and its components. a. Sagging, deformed, loose or damaged fan aerofoil, or dislodgement of any of the fan components; b. Check that the safety cable is present and secured properly to the mounting structure with as little slack as possible; c. Presence of loose bolts and nuts on the fan components and supporting structures; d. Signs of frayed, sagging, or damaged guy wires (if present); e. Signs of damaged aerofoil retainer devices; f. Signs of corrosion, pitting, or cracks on fan components and their supporting structures; g. Observe and ensure the motion of the fan do not wobble during operation; h. Presence of water stains, efflorescence, moulds which may lead to corrosion of fan and its components; and i. Review the analytical and predictive data in the Building Management Systems (BMS) to identify defects in the operation and condition of the HVLS fan and its components. Data includes excessive vibration, irregular oscillation, etc.

3. Building owners and responsible parties should look out for the following signs when inspecting the **supporting structures** of the HVLS fan.

    a. Missing, sagging, loose, deformed or otherwise damaged supporting structure of the fan and its connecting bolts and nuts alteration;

    b. Signs of corrosion, rust or other forms of deterioration and damage on the supporting structure and its connecting bolts and nuts;

    c. Inappropriate alteration or removal of the supporting structures and connections, such as safety cables, guy wires and bolts and nuts, of the fan; and

    d. Inappropriate addition of fixtures or equipment (e.g., piping works, additional display, signages, etc.) to their supporting structure such that additional loads are imposed beyond the allowable loads that the supporting structures are designed to carry.

4. Building owners and responsible parties should look out for the following signs when inspecting the **structural elements** to which the HVLS fan are installed such as columns, beams and slab.

    a. Concrete crack lines;

    b. Spalling concrete;

    c. Corrosion;

    d. Water stains or water seepage;

    e. Termite infestation; and

    f. Other signs of deterioration.

5. Should there be any defects observed, building owners and responsible parties are advised to contact the supplier, manufacturer, specialist or a registered Professional Engineer for advice and repair/replacement.

5.5 HIGH VOLUME LOW SPEED (HVLS) FAN INSTALLATION CHECKLIST

Building: Company:

Block / Storey: Name of Installer:

Date of Installation: Name of Supervisor:

S/N	Description	✓/×/NA	Remarks
1.1	**HVLS Fan Installation**		
1.2	Approved Shop drawing endorsed by a Professional Engineer (PE) is submitted and available on installation site		
1.3	Installation is carried out by an installer familiar with the installation requirements of the product		
1.4	The fan is secured with safety cables as a safety measure according to the manufacturer's recommendation and specification		
1.5	The fan aerofoil is secured with safety retainer device as a safety measure according to the manufacturer's recommendation and specification, to prevent aerofoil from detaching from the fan body		
1.6	The fan has safety mechanism to stop operating automatically upon impact or malfunction		
1.7	The supporting structure of the fan are not used to support other building fixtures and vice versa		
1.8	The mounting location and the supporting structure are able to support the weight of the fan as per the PE design		
1.9	Mark out locations of fixing points prior to installation to ensure the fixing points are positioned well within the available supporting structure		

1.10	Fixing to steel soffit of composite slab is carried out in accordance with the approved drawings and the requirements of the specific product		
1.11	Non-destructive pull-out test are conducted at critical locations such as at concrete ceiling		
1.12	Provision of access for maintenance[33] to facilitate efficient and effective maintenance to be carried (e.g., sufficient floor space or area to facilitate the machinery or ladder to reach the HVLS fan fixtures at high ceiling and adequate access panels for its concealed fixture support		
2.0	**Connections and Anchors**		
2.1	Anchors, screws and rivets are made of corrosion resistant material; preferably made of stainless-steel with minimum grade SS304 when used in area subjected to external weathering or wet condition, and minimally made of galvanised-steel when used in indoor space with dry condition		
2.2	The required embedment depth of anchors should extend beyond the concrete cover and exclude the thickness of any plaster layer		
2.3	Suitable type of anchors are used in accordance to the approved drawings as prescribed by the Professional Engineer		
2.4	Anchors, screws and rivets are procured from reliable manufacturers or suppliers and installed in accordance with the manufacturer's installation guidelines		
2.5	Anchor installer is well trained and has attend courses on anchor installation by established course provider		

[33] Please refer to the Design for Maintainability (DfM) Guide for more information.

5.6 HIGH VOLUME LOW SPEED (HVLS) FAN MAINTENANCE AND INSPECTION CHECKLIST

Building: Company:

Block / Storey: Name of Supervisor:

Inspection frequency: Date of Inspection:

S/N	Description	✓/×/NA	Remarks
1.0	**Documentation**		
1.1	A set of approved drawings, manufacturer/supplier's operation and maintenance manual (OEM) and warranty documentation are available		
1.2	Review records of any known maintenance problems and previous rectifications carried out on the fixtures, including data from the Building Management Systems (BMS) such as excessive vibration, irregular oscillation, etc.		
1.3	Place emphasis on HVLS fan fixtures over high human traffic and public assembly areas such as waiting/seating areas, lobbies, entrance, food courts, etc.		
1.4	Place emphasis on HVLS fan fixtures subjected to unfavourable environmental conditions such as exposure to wind, rain, moisture, condensation, exhaust, heat and vibration that may accelerate the deterioration of fixtures		
1.5	Photograph and document details of any new defects (e.g., location, defect observed, repair work that was carried out, etc.)		
2.0	**HVLS Fan and its Components**		
2.1	No sagging, deformed, loose, corroded or damaged fan aerofoil, and/or dislodgement of any of the fan bolts and nuts, components and its aerofoil retainer devices		
2.2	The safety cable and guy wire is secured properly to the mounting structure with as little slack as possible		

2.3	No signs of frayed, sagging, or damaged guy wires (if present)		
2.4	Observe and ensure the motion of the fan do not wobble during operation		
2.5	No water stains, efflorescence, moulds on the fan and its components		
3.0	**Supporting Structures – Hanger rods, Brackets, And Connections**		
3.1	No missing, sagging, deformed, loose, corroded or otherwise damaged supporting structure of the fan and its connecting bolts and nuts		
3.2	No inappropriate alteration or removal of the supporting structures and connections, such as safety cables, guy wires and bolts and nuts		
3.3	No supporting structures of the fan are used to support other building fixtures and vice versa (e.g., pipes, display screens, signages, etc.)		
4.0	**Structural Elements – Columns, Beams, And Slab**		
4.1	No concrete crack lines around the connections		
4.2	No spalling concrete		
4.3	No corrosion on steel structure		
4.4	No water stains or water seepage		
4.5	No termite infestation		
4.6	No other signs of deterioration		

Note:

Should there be any defects observed, building owners and responsible parties are advised to contact the supplier, manufacturer, specialist or a registered Professional Engineer for advice and repair/replacement.

6 OVERHEAD FIXTURES

Modern commercial and residential spaces include many fixtures installed for various purposes such as huge chandeliers and lightings, large advertisement displays, signages, art installations, festive decorative fittings, exhibits, etc. These fixtures are also getting heavier and may require fixing at height or onto ceilings and some may even require metal frames to act as the supporting structure. As such fixtures are commonly installed in crowded public places, any incident involving dislodgement of the fixtures could pose a safety risk to the public.

This chapter advises the industry on good practices for the design, installation and maintenance of overhead fixtures to prevent their dislodgement and potentially injuring the public.

Examples of overhead fixtures are shown in Figure 6-1 to Figure 6-6.

Figure 6-1: Chandelier in Lobby

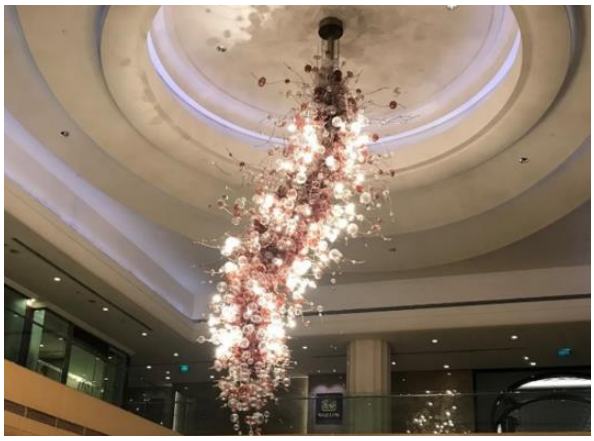


Figure 6-2: Chandelier/Art Decoration in Lobby

Figure 6-3: Media Display Screen in Shopping Mall

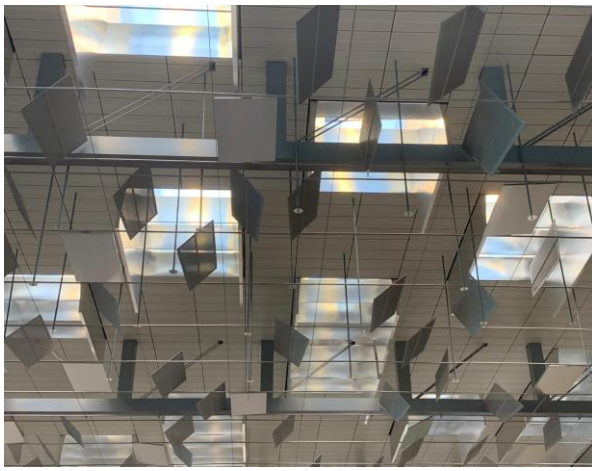


Figure 6-4: Overhead Panel Fitting

Figure 6-5: LED Screen at Ceiling Soffit

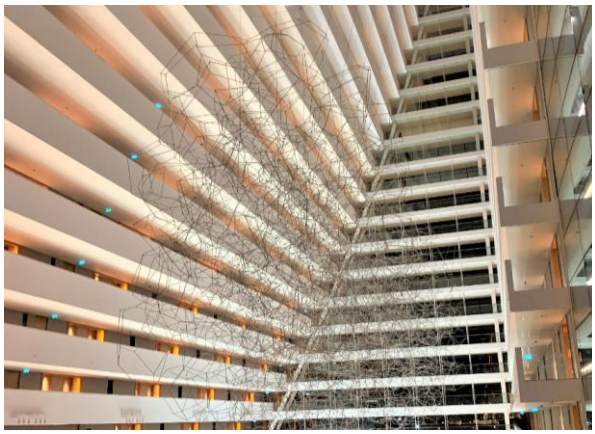


Figure 6-6: Art Decoration in Hotel Lobby

6.1 Possible Causes of the Dislodgement of Overhead Fixtures

Lack of maintenance and improper use of overhead fixtures can cause the fixtures and their supporting structure to deteriorate and result in partial or full dislodgement. The possible causes of the dislodgement of overhead fixtures are as follows:

POSSIBLE CAUSES OF DISLODGEMENT OF OVERHEAD FIXTURES
1. Inadequate inspections and ineffective maintenance plans (e.g., inspection done on an irregular/prolonged interval or inspection carried out by untrained personnel, etc.) that lead to undetected or unaddressed defects and issues in the fixtures, such as: a. Corrosion of fixtures such as the hanging system[34] or their supporting structures; b. Missing screws, bolts and nuts and loose parts; c. Spalling and crack of the supporting concrete elements; and d. Other forms of wear and tear.

[34] Common hanging system used for overhead fixtures include chain hung, chord hung, or down-rod mounted.

2. Inappropriate alteration or removal of the supporting structures and connections, such as hangers, brackets, and safety cables (if present).
3. Inappropriate addition of fixtures or equipment (e.g., suspended ceiling, cabinets, piping works, additional display, signages, etc.) to the overhead fixtures or their supporting structure such that additional loads are imposed beyond the allowable loads that the fixtures or their supporting structures are designed to carry.
4. Installation not carried out according to the manufacturer's guide and recommendations.
5. Poor workmanship and improper installation of the fixtures.
6. Spinning or swaying of the hanging fixtures causing the supporting structure to loosen and damaging the hanging system.

6.2 Good Practices for the Design and Installation of Overhead Fixtures

The industry should adopt the following good practices when designing and installing overhead fixtures and the supporting structures to ensure the safety of building users and maintenance personnel.

RECOMMENDATIONS (DESIGN AND INSTALLATION)
1. Conform to established standards[35] for the design and installation of overhead fixtures. These standards[36] includes: a. Eurocode Standard (BS EN 1991 Actions on Structures); b. Eurocode Standard (BS EN 1993 Design of Steel Structures);

[35] Please refer to the prevailing applicable version of the Codes and Standards.
[36] Refer to chapter "Mechanical Electrical and Plumbing (MEP) Fixtures" for list of established standards relevant to MEP components and its fixtures.

c. Eurocode Standard (BS EN 1999 Design of Aluminium Structures); and

d. Eurocode Standard (BS EN 1090 Structural Steel and Aluminium).

Note: Refer to Consumer Protection (Safety Requirements) Regulations for information on products that are considered as controlled goods requiring to be registered with the authority and affixed with the SAFETY Mark

2. Engage a product specialist, manufacturer or a registered Professional Engineer in the Civil Engineering discipline to design and supervise the installation of the supporting structures of the overhead fixtures. The design should consider the following:

    a. Loads such as the weight of fixtures and its supporting frames;

    b. Robustness such as provisions for redundancy[37] and consideration of uneven distributed load in a multiple hanging fixture;

    c. The overhead fixtures are designed such that the failure or removal of a single hanger or support does not cause progressive collapse of the system;

    d. Capacity of the supporting hangers, brackets and anchors based on the manufacturer's recommendation[38]; and

    e. Design and component choices for overhead fixtures and their supporting structures installed at the exterior of the building should be suitable for their intended use taking into consideration the influence from the higher wind load and the effect of external weathering.

3. The following should be considered for the anchors, screws and rivets used for installation.

[37] Provisions for redundancy to accommodate unexpected additional live loads such as those due to the accumulation of water, wind gust and displacement of overhead fixtures, etc., could be considered during the design of the supporting structures.

[38] The use of durable and corrosion-resistant material for load bearing components of the fixture and its supporting structure should be considered.

a. Corrosion resistant material such as stainless-steel of minimum grade SS304 should preferably be used for the anchors, screws and rivets subjected to external weathering or wet conditions. For indoor space with dry condition, the use of galvanised-steel fasteners shall be a minimum requirement;

b. Design and installation of anchors to conform to BS 8539:2012 - Code[39] of Practice for Selection and Installation of Post-Installed Anchors in Concrete and Masonry;

c. The required embedment depth for the anchor installation into the reinforced concrete structural elements should extend beyond the concrete cover to the reinforcement layer when measured from the base material, and this required embedment depth should exclude the thickness of any plaster layer;

d. Anchor used should be suitable for anchoring into concrete (e.g., cracked-approved anchor) to account for microcracks in concrete;

e. Consult the supplier, manufacturer, or a registered Professional Engineer in the Civil Engineering discipline for the suitable type of anchors, screws and rivets to be used;

f. Procure anchors, screws and rivets from reliable manufacturers and suppliers;

g. Adhere to the installation guide provided by the manufacturers;

h. Attend courses on anchor installation by established course provider; and

i. Carry out testing of anchors according to BS 8539:2012 and the latest edition of the normative reference published by the Construction Fixings Association Guidance Note – Procedure for Site Testing Construction Fixings.

4. Procure fixtures with competent components and connection system from reliable manufacturers and suppliers who provide warranty/maintenance support.

[39] Please refer to the prevailing applicable version of the Codes and Standards.

5. Other design and installation considerations include:

    a. Carry out visual inspection on an annual basis and a full inspection at intervals of not more than three years as recommended in BS 8210:2020 Code[40] of Practice for Facilities Maintenance Management or as recommended by the manufacturer, whichever is earlier;

    b. Supplier, manufacturer or specialist and Professional Engineer (PE) should be notified to provide alternative support system in the event that hangers and other supporting structures cannot be installed according to design due to obstruction by other building;

    c. Ensure the fixtures which require additional hanging cable for stability are properly secured;

    d. Inspect item carefully before installing. If there is any damage or obvious defects, to cease installation;

    e. Installation should be carried out by a installer familiar with the installation requirements of the product;

    f. Verify the mounting location and that the supporting structure can support the weight of the heavy fixtures as per the Professional Engineer (PE) design;

    g. The overhead fixtures should not be used to support other building fixtures and vice versa unless specifically designed to do so;

    h. Fixing to steel soffit of composite slab should be carried out in accordance with the guidelines and requirements of the specific product;

    i. Conduct non-destructive pull-out test at critical locations for heavy fixtures;

    j. Provision of access for maintenance[41] to facilitate efficient and effective maintenance to be carried (e.g., sufficient floor space or area to facilitate the machinery or ladder to reach the overhead

[40] Please refer to the prevailing applicable version of the Codes and Standards.
[41] Please refer to the Design for Maintainability (DfM) Guide for more information.

fixtures at high ceiling and adequate access panels for its concealed fixture support); and

k. Engage the supplier, manufacturer, specialist or a registered Professional Engineer in the Civil Engineering discipline to design and supervise any alteration or modification to the overhead fixtures or their supporting structure.

6.3 Regular Inspection and Maintenance of Overhead Fixtures

Poorly maintained and defective fixtures pose a safety risk to the public. Building owners and responsible parties should carry out regular inspections and maintenance of overhead fixtures and adopt the following good practices.

RECOMMENDATIONS (MAINTENANCE AND INSPECTION)
1. Schedule for regular inspection of the overhead fixtures and their supporting structures, and keep inspection records for future reference. The following recommendations may be considered: a. Carry out visual inspection on an annual basis and a full inspection at intervals of not more than three years as recommended in BS 8210:2020 Code[42] of Practice for Facilities Maintenance Management or as recommended by the manufacturer, whichever is earlier; b. Check validity/expiry of warranty for product and its supporting structures; c. Maintenance and inspection may be carried out by in-house maintenance team, or by external maintenance firm engaged by the building owners or responsible parties. Building owners or responsible parties may also engage a specialist or a Professional Engineer (PE) in the Civil Engineering discipline to carry out the inspection;

[42] Please refer to the prevailing applicable version of the Codes and Standards.

d. Place emphasis on overhead fixtures over high human traffic areas and high density public assembly areas where members of the public would be present for a substantial length of time (e.g., waiting/seating areas, lobbies, entrance, food courts, etc.);

e. Place emphasis on overhead fixtures subjected to unfavourable environmental conditions such as exposure to wind, rain, moisture, condensation, exhaust, heat and vibration that may accelerate the deterioration of fixtures;

f. Keep records of any known maintenance problems and previous rectifications carried out on the overhead fixtures. Useful plans, sketches, photographs and tabulations could also be included to illustrate the findings of the inspection;

g. Adequately photograph and document details of any new defects (e.g., location, defect observed, repair work that was carried out, etc.);

h. Implement a maintenance plan to identify defects[43] early, conduct a detailed investigation to ascertain the root causes of such defects, and promptly repair the defects;

i. Building owners and responsible parties are recommended to incorporate monitoring and predictive element, such as sensors and artificial intelligence, into their Building Management Systems (BMS) to collect and analyse trends and operating conditions of the overhead fixtures and its components. Parameters that may be monitored include humidity, vibration, etc., so as to prevent excessive movement, vibration or corrosion to the overhead fixtures and their supporting structures; and

j. Engage the supplier, manufacturer, specialist or a registered Professional Engineer to address any defects that warrant further investigation.

[43] Building owners and responsible parties are advised to promptly investigate and address the root cause of defects especially defects such as spalling concrete, water seepage and excessive accumulation of water.

2. Adhere to the maintenance manual provided by the supplier or manufacturer of the fixtures, which may include the following:

    a. Replacement of deteriorated parts and components such as bolts and nuts, hangers and screws;

    b. Replacement of deteriorated or detached anchors with stainless-steel anchors;

    c. Tightening of loose nuts, hangers and cables; and

    d. Consult the supplier, manufacturer, specialist or a registered Professional for any repair, replacement or alteration to the supporting structure.

3. Promptly inspect and address any maintenance issues reported by tenants or members of the public such as detached or loose components, slanted fixtures, etc.

6.4 Inspection Guidelines for Overhead Fixtures

Building owners and responsible parties should be vigilant and look out for any of the following warning signs of damage and deterioration of the overhead fixtures, their supporting structures and the structural elements to which they are installed.

SIGNS OF DAMAGE OR DETERIORATION
1. Inspection should be carried based on approved drawings, manufacturer's guide and product manual. Thorough inspection should be carried out, especially at areas of major concern such as public area, high traffic area and weather prone area.
2. Building owners and responsible parties should look out for the following signs when inspecting the fixtures and its components. a. Sagging, deformed, loose, damaged, or dislodged fixture and its components;

b. Presence of loose bolts and nuts on the fixtures components and supporting structures;

c. Signs of frayed and sagging of the hanging system or damaged guy wires (if present);

d. Check that the safety cable (if present) is secured properly to the mounting structure with as little slack as possible;

e. Presence of water stains, efflorescence and moulds which may lead to corrosion of the fixtures and its components;

f. Signs of corrosion, pitting, or cracks on fixtures components and their supporting structures;

g. Additional fixtures such as lighting and signages being hanged below other fixtures which are not designed to carry such additional loads; and

h. Review the analytical and predictive data in the Building Management Systems (BMS) to identify defects in the operation and condition of the overhead fixtures and its components. Data includes excessive vibration in the fixtures, humidity in the environment, etc.

3. Building owners and responsible parties should look out for the following signs when inspecting the **supporting structures** of the fixtures.

    a. Missing, sagging, kinked, deformed, or otherwise damaged supporting structure of the fixtures, such as hangers, frames and connecting bolts and nuts;

    b. Inappropriate alteration or removal of the supporting structure, such as hangers, frames and bolts and nuts;

    c. Signs of corrosion, rust or other forms of deterioration and damage on the supporting structure, such as hangers, frames and connecting bolts and nuts; and

    d. Additional fixtures such as lighting, cabinets, display screen that do not have an independent support or are dislodged and are imposing additional loads on the supporting structures of the MEP fixture.

4. Building owners and responsible parties should look out for the following signs when inspecting the **structural elements** to which the fixtures are installed such as columns, beams and slab.

    a. Concrete crack lines;

    b. Spalling concrete;

    c. Corrosion;

    d. Water stains or water seepage;

    e. Termite infestation; and

    f. Other signs of deterioration.

5. Should there be any defects observed, building owners and responsible parties are advised to contact the supplier, manufacturer, specialist or a registered Professional Engineer for advice and repair/replacement.

6.5 OVERHEAD FIXTURES INSTALLATION CHECKLIST

Building: Company:

Block / Storey: Name of Installer:

Date of Installation: Name of Supervisor:

S/N	Description	✓/×/NA	Remarks
1.0	**Overhead Fixtures Installation**		
1.2	Approved shop drawing endorsed by a Professional Engineer (PE) is submitted and available on installation site		
1.3	Mark out locations of fixing points prior to installation to ensure the fixing points are positioned well within the available supporting structure		
1.4	Hangers are not to be bent or kinked in an attempt to avoid building services and obstructions during installation		
1.5	Secondary members are installed according to design when hangers are obstructed by building services		
1.6	The overhead fixtures are not used to support other building fixtures and vice versa		
1.7	Fixing to steel soffit of composite slab is carried out in accordance with the approved drawings and the requirements of the specific product		
1.8	Fixtures which require additional hanging cable for stability are properly secured		
1.9	Fixtures are inspected and free from any damage or obvious defects before installing		
1.10	Installation is carried out by an installer familiar with the installation requirements of the product		

1.11	The mounting location and the supporting structure are able to support the weight of the heavy fixtures as per the Professional Engineer (PE) design		
1.12	Non-destructive pull-out test are conducted at critical locations such as at concrete ceiling		
1.13	Provision of access for maintenance[44] to facilitate efficient and effective maintenance to be carried (e.g., sufficient floor space or area to facilitate the machinery or ladder to reach the overhead fixtures at high ceiling and adequate access panels for its concealed fixture support)		
2.0	**Connections and Anchors**		
2.1	Anchors, screws and rivets are made of corrosion resistant material; preferably made of stainless-steel with minimum grade SS304 when used in area subjected to external weathering or wet condition, and minimally made of galvanised-steel when used in indoor space with dry condition		
2.2	The required embedment depth of anchors should extend beyond the concrete cover and exclude the thickness of any plaster layer		
2.3	Suitable type of anchors are used in accordance to the approved drawings as prescribed by the Professional Engineer		
2.4	Anchors, screws and rivets are procured from reliable manufacturers or suppliers and installed in accordance with the manufacturer's installation guidelines		
2.5	Anchor installer is well trained and has attend courses on anchor installation by established course provider		

[44] Please refer to the Design for Maintainability (DfM) Guide for more information.

6.6 OVERHEAD FIXTURES MAINTENANCE AND INSPECTION CHECKLIST

Building: Company:

Block / Storey: Name of Supervisor:

Inspection frequency: Date of Inspection:

S/N	Description	✓/×/NA	Remarks
1.0	**Documentation**		
1.1	A set of approved drawings, manufacturer/supplier's operation and maintenance manual (OEM) and warranty documentation are available		
1.2	Review records of any known maintenance problems and previous rectifications carried out on the fixtures, including data from the Building Management Systems (BMS) such as temperature and humidity fluctuation, excessive vibration, etc.		
1.3	Place emphasis on overhead fixtures over high human traffic and public assembly areas such as waiting/seating areas, lobbies, entrance, food courts, etc.		
1.4	Place emphasis on overhead fixtures subjected to unfavourable environmental conditions such as exposure to wind, rain, moisture, condensation, exhaust, heat and vibration that may accelerate the deterioration of fixtures		
1.5	Photograph and document details of any new defects (e.g., location, defect observed, repair work that was carried out, etc.)		
2.0	**Overhead Fixtures and Components**		
2.1	No uneven, sagging, deformed, damaged, corroded or dislodged overhead fixtures, bolts and nuts, and its components		
2.2	No signs of frayed or sagging of the hanging system or damaged guy wires (if present)		

2.3	The safety cable (if present) is secured properly to the mounting structure with as little slack as possible		
2.4	No fixture or equipment such as lighting, piping, ducts, and diffusers is dislodged and imposing its self-weight onto the suspended overhead fixtures components or frame		
2.5	No water stains, efflorescence, or moulds		
3.0	**Supporting Structures – Hangers, Frames, And Connections**		
3.1	No missing, loose, bent, kinked, corroded, sagging, damaged or inappropriately altered supporting structures such as hangers, frames, bolts, nuts, screws, clips, brackets, etc.		
3.2	No hanger is used to support other building fixtures not designed for (e.g., cabinets, pipes, display screens, signages, etc.)		
3.3	No signs of other forms of deterioration and damage on the hangers, frames and connecting bolts and nuts		
4.0	**Structural Elements – Columns, Beams, And Slab**		
4.1	No concrete crack lines around the connections		
4.2	No spalling concrete		
4.3	No corrosion on steel structure		
4.4	No water stains or water seepage		
4.5	No termite infestation		
4.6	No other signs of deterioration		

Note:

Should there be any defects observed, building owners and responsible parties are advised to contact the supplier, manufacturer, specialist or a registered Professional Engineer for advice and repair/replacement.

7 SPALLING CONCRETE

Spalling concrete is a condition whereby the external part of the concrete delaminates off the main concrete body and falls off. Spalling concrete poses a safety risk to the public especially when it dislodges from high-rise buildings. If left unattended to, spalling concrete can deteriorate further and could affect the structural integrity of the building. The probability of it happening increase as the building ages. Therefore, early detection is the best preventive measure to prevent such incident from happening. This guideline presents to the industry on good practices for the maintenance and detections of early signs of spalling concrete, and the ways to repair it.

Examples of spalling concrete are shown in Figure 7-1 to Figure 7-4.

Figure 7-1: Spalling Concrete at Facade Edge

Figure 7-2: Spalling Concrete at Roof Eave

Figure 7-3: Spalling Concrete at Ceiling Soffit

Figure 7-4: Spalling Concrete at Ledge

7.1 Common Causes of Spalling Concrete

Concrete is inherently porous and contains many hairline cracks which is susceptible to ingress of air, water and chemicals. Spalling concrete develops as a result of the ingress of these environmental elements which react with the underlying concrete and reinforcing bars causing them to deteriorate and corrode. Since the rust (iron oxide) occupies more volume than the original reinforcing bars, it pushes against the concrete cover to cause it to crack and bulge and finally fall off. A lack of maintenance of the concrete building can cause or accelerate the deterioration of the concrete, which may result in a spalling concrete. The common causes of spalling concrete are as follows:

COMMON CAUSES OF SPALLING CONCRETE
1. Cracks widening and growth in concrete from excessive building movements, overloading and long term drying shrinkage.
2. Low quality or low-grade concrete used as a result of manual batching process commonly found in older buildings.
3. Concrete subjected to weathering process under the effect of rain, wind and chemicals which is common for ageing buildings and buildings situated near coastal regions.
4. Inadequate depth of concrete cover due to Improper placement of concrete and its reinforcing steel bar during casting work.
5. Improper or incorrect repair of spalling concrete, cracks and holes such as incorrect repair procedure or use of unsuitable materials. This will result in the spalling concrete continuing to deteriorate undetected underneath the fresh coats of repair.
6. Bare concrete without any protective coating such as paint or sealer is more susceptible to effects of weathering and ingress of air, water and chemicals.
7. Humid enclosed space which encourages concrete carbonation.

8. Undetected or prolonged water ponding and water seepage into concrete, which commonly occurs on roof slab and external elements of buildings.

9. Installation of fixtures or equipment to the concrete without checking the condition of the existing concrete which might have already been in a deteriorated condition. This will cause further cracks to develop and damage the concrete.

7.2 Good Practices for the Inspection and Maintenance of Concrete Building

Defective spalling concrete poses a safety risk to the public. Concrete spalling generally manifest at the building periphery and exteriors, floor below roof structures exposed to the elements and wet areas that are prone to water ingress from rain and other sources. These areas are sometimes hidden from view by suspended ceilings and if unattended to for a long time, could lead to large extent of spalled concrete dislodgements. Building owners and responsible parties should carry out regular inspections and maintenance to detect spalling concretes and adopt the following good practices.

RECOMMENDATIONS (MAINTENANCE AND INSPECTION)

1. Schedule for regular inspection of the building and its concrete structures, and keep inspection records for future reference. The following recommendations may be considered:

    a. Carry out visual inspection on an annual basis and a full inspection at intervals of not more than three years as recommended in BS 8210:2020 Code[45] of Practice for Facilities Maintenance Management;

    b. Maintenance and inspection may be carried out by in-house maintenance team, or by external maintenance firm engaged by the building owners or responsible parties. Building owners or

[45] Please refer to the prevailing applicable version of the Codes and Standards.

responsible parties may also engage a specialist or a professional engineer (PE) in the Civil Engineering discipline to carry out the inspection;

c. Place emphasis on concrete structures subjected to unfavourable environmental conditions such as exposure to wind, rain, moisture, condensation, exhaust, heat and vibration that may accelerate the deterioration of building structures;

d. Keep records of any known maintenance problems and previous rectifications carried out on the building structures. Useful plans, sketches, photographs and tabulations could also be kept to illustrate the findings of the inspection;

e. Adequately photograph and document details of any new defects (e.g., location, defect observed, repair work that was carried out, etc.);

f. Implement a maintenance plan to identify defects[46] early, conduct a detailed investigation to ascertain the root causes of such defects, and promptly repair the defects; and

g. Engage the concrete protective product supplier/manufacturer[47], concrete repair specialist[48] or a registered Professional Engineer in the Civil Engineering discipline to address any defects that warrant further investigation, such as repeated spalling or seepage at same or similar locations.

2. Carry out the following maintenance to the building and its concrete structure, which may include the following:

    a. Regular inspection on concrete surfaces by removing cladding and suspended ceiling or through the use of an effective visual or

[46] Building owners and responsible parties are advised to promptly investigate and address the root cause of defects especially defects such as spalling concrete, water seepage and excessive accumulation of water.

[47] The list (non-exhaustive) of concrete protective product supplier and manufacturer may be found under the section 'Registered Contractors>Supply>SY02-Chemicals' in the 'BCA Directory of Registered Contractor and Licensed Builder'.

[48] The list (non-exhaustive) of registered contractors for concrete repair, corrosion protection and waterproofing installation may be found under the section 'Registered Contractors>Construction Related>CR05-Concrete Repairs' in the 'BCA Directory of Registered Contractor and Licensed Builder'.

scanning technology, especially at weather prone areas, high traffic areas and public areas;

b. Consider applying protective coating to concrete surfaces such as waterproofing membrane or anti-carbonation coating according to manufacturer recommendation for areas that requires more protection;

c. Carrying out painting works and sealing up holes to protect the concrete surfaces from weathering elements;

d. Ensure proper ventilation to prevent humidity built up, which accelerate concrete carbonation and deterioration; and

e. Remove stagnant water and addressing water seepage and water leakage problem.

3. Promptly inspect and address any maintenance issues reported by tenants or members of the public, such as water leaks from roof, plumbing and air-conditioning and mechanical ventilation systems.

7.3 Inspection Guidelines for Spalling Concrete

Building owners and responsible parties should be vigilant and look out for any of the following warning signs of damage and deterioration that may indicate presence of spalling concrete:

SIGNS OF DAMAGE OR DETERIORATION
1. Building owners and responsible parties should look out for the following signs when inspecting the **concrete structure**. a. Hollow sounds when concrete surfaces are tapped with a tapping tool, which indicates the concrete has delaminate and spalling is imminent; b. Deformed or uneven concrete surfaces, which could be a sign of spalling concrete bulging; c. Concrete crack lines on concrete surfaces; and

d. Presence of water stains, efflorescence, moulds, and water leaks on the concrete surfaces.

7.4 Repair Method for Spalling Concrete

A well repaired spalling concrete not only prevents the recurrence of the defects but also stops spalling concrete from propagating to larger areas. It prolongs the life and performance of the building and prevents having to carry out major repair works due to the continuous deterioration of spalling concrete.

RECOMMENDATIONS (REPAIR)
1. Conform to established standards for the protection and repair of concrete structures. This standard includes: a. British/European Standard (BS EN 1504 Part 1 to 10 Products and Systems for the Protection and Repair of Concrete Structures).
2. Engage a concrete repair contractor or specialist[49] to carry out the repair work or a supplier/ manufacturer[50] who specialises in concrete repair products and applications.
3. For conservation buildings, to consult relevant agency for advice and requirements on repair method and materials to be used.
4. Carry out repair to minor spalling concrete in accordance to following best practice: a. Remove loose concrete pieces and trim the affected area until sound concrete is observed;

[49] The list (non-exhaustive) of registered contractors for concrete repair, corrosion protection and waterproofing installation may be found under the section 'Registered Contractors>Construction Related>CR05-Concrete Repairs' in the 'BCA Directory of Registered Contractor and Licensed Builder'.
[50] The list (non-exhaustive) of concrete protective product supplier and manufacturer may be found under the section 'Registered Contractors>Supply>SY02-Chemicals' in the "BCA Directory of Registered Contractor and Licensed Builder.

b. Clean and remove rust from reinforcing steel bars using a wire brush and apply antirust paint to the reinforcing steel bars;

c. Apply bonding agent to the reinforcing bars and concrete surfaces to ensure proper adhesion to the repair mortar;

d. Apply cementitious repair mortar suitable for spalling concrete repair to the affected areas; application should be in multiple layers to ensure proper adhesion of the grouts;

e. Wait for the repaired areas to be cured for a time period recommended by the product manufacturer;

f. Apply paint and / or protective coating to protect the affected area for long term protection; and

g. Apply architectural finishes after the repair work is completed.

5. Owners and responsible parties are advised to engage a registered Professional Engineer in the Civil Engineering discipline for advice on the structural repair if the following severe conditions are encountered where special repair method or strengthening to the structure may be required:

    a. Spalling concrete affecting beyond the depth of the reinforcing steel bars or where the prestressing/ post-tensioning strands are exposed;

    b. Severely rusted and / or broken reinforcing steel bars;

    c. Spalling concrete affecting large areas or multiple areas;

    d. Water seepage or failure of waterproofing system especially at basement or roof;

    e. Honeycomb on concrete element whereby the coarse aggregates are exposed, and its void not filled by cement mortar; and

    f. Through cracks and / or holes on concrete element.

7.5 SPALLING CONCRETE MAINTENANCE AND INSPECTION CHECKLIST

Building: Company:

Block / Storey: Name of Supervisor:

Inspection frequency: Date of Inspection:

S/N	Description	✓/×/NA	Remarks
1.0	**Documentation and Tools**		
1.1	Check for records of repeated spalling concrete and rectification works carried out at same or similar locations		
1.2	Place emphasis on concrete structures subjected to unfavourable environmental conditions such as exposure to wind, rain, moisture, condensation, exhaust, heat and vibration that may accelerate the deterioration of building structures		
1.3	Photograph and document details of any new defects (e.g., location, defect observed, repair work that are carried out, etc.)		
1.4	Prepare inspection tools such as tapping tools and torch light, or an effective visual or scanning technology for inspection on concrete surfaces.		
2.0	**Signs of Wear and Tear on Protective Coating**		
2.1	Deteriorated of peeled off protective coating such as waterproofing membrane or anti-carbonation coating		
2.2	Deteriorated of peeled off paint coat		
3.0	**Signs of Spalling Concrete**		
3.1	Hollow sounds when concrete surfaces are tapped with a tapping tool, which indicates the concrete has delaminate and spalling is imminent		

3.2	Deformed or uneven concrete surfaces, which could be a sign of spalling concrete bulging. To carry out step 3.1 to verify if it is spalling concrete		
3.3	Concrete crack lines on concrete surfaces, which could be a sign of spalling concrete. To carry out step 3.1 to verify if it is spalling concrete		
3.4	Presence of water stains, efflorescence, moulds, and water leaks on the concrete surfaces, which could be a sign of spalling concrete. To carry out step 3.1 to verify if it is spalling concrete		

Note:

Should there be any defects or signs that warrant further investigation, such as repeated spalling or seepage at same or similar locations, building owners and responsible parties are advised to engage a concrete repair contractor/ specialist[51], or a concrete protective product supplier/ manufacturer[52], or a registered Professional Engineer in the Civil Engineering discipline for advice.

In addition, owners and responsible parties are advised to engage a registered Professional Engineer in the Civil Engineering discipline for advice on the structural repair if the following severe conditions are encountered where special repair method or strengthening to the structure may be required:

a. Spalling concrete affecting beyond the depth of the reinforcing steel bars or where the prestressing/ post-tensioning strands are exposed;
b. Severely rusted and / or broken reinforcing steel bars;
c. Spalling concrete affecting large areas or multiple areas;
d. Water seepage or failure of waterproofing system especially at basement or roof;
e. Honeycomb on concrete element whereby the coarse aggregates are exposed, and its void not filled by cement mortar;
f. Through cracks and / or holes on concrete element.

[51] The list (non-exhaustive) of registered contractors for concrete repair, corrosion protection and waterproofing installation may be found under the section 'Registered Contractors>Construction Related>CR05-Concrete Repairs' in the 'BCA Directory of Registered Contractor and Licensed Builder'.
[52] The list (non-exhaustive) of concrete protective product supplier and manufacturer may be found under the section 'Registered Contractors>Supply>SY02-Chemicals' in the 'BCA Directory of Registered Contractor and Licensed Builder'.

7.6 SPALLING CONCRETE MINOR REPAIR CHECKLIST

Building: Company:

Block / Storey: Name of Supervisor:

Inspection frequency: Date of Inspection:

S/N	Description	✓/×/NA	Remarks
1.0	**Repair Procedure for Minor Spalling Concrete**		
1.1	Remove loose concrete pieces and trim the affected area until sound concrete is observed		
1.2	Clean and remove rust from reinforcing steel bars using a wire brush and apply antirust paint to the reinforcing steel bars		
1.3	Apply bonding agent to the reinforcing bars and concrete surfaces to ensure proper adhesion to the repair mortar		
1.4	Apply cementitious repair mortar suitable for spalling concrete repair to the affected areas; application should be in multiple layers to ensure proper adhesion of the grouts		
1.5	Wait for the repaired areas to be cured for a time period recommended by the product manufacturer		
1.6	Apply paint and / or protective coating to protect the affected area for long term protection		
1.7	Apply architectural finishes after the repair work is completed		

Note:

Should there be any defects or signs that warrant further investigation, such as repeated spalling or seepage at same or similar locations, building owners and

responsible parties are advised to engage a concrete repair contractor/ specialist[53], or a concrete protective product supplier/ manufacturer[54], or a registered Professional Engineer in the Civil Engineering discipline for advice.

In addition, building owners and responsible parties are advised to engage a registered Professional Engineer in the Civil Engineering discipline for advice on the structural repair if the following severe conditions are encountered where special repair method or strengthening to the structure may be required:

a. Spalling concrete affecting beyond the depth of the reinforcing steel bars or where the prestressing/ post-tensioning strands are exposed;
b. Severely rusted and / or broken reinforcing steel bars;
c. Spalling concrete affecting large areas or multiple areas;
d. Water seepage or failure of waterproofing system especially at basement or roof;
e. Honeycomb on concrete element whereby the coarse aggregates are exposed, and its void not filled by cement mortar;
f. Through cracks and / or holes on concrete element.

[53] The list (non-exhaustive) of registered contractors for concrete repair, corrosion protection and waterproofing installation may be found under the section 'Registered Contractors>Construction Related>CR05-Concrete Repairs' in the 'BCA Directory of Registered Contractor and Licensed Builder.
[54] The list (non-exhaustive) of concrete protective product supplier and manufacturer may be found under the section 'Registered Contractors>Supply>SY02-Chemicals' in the 'BCA Directory of Registered Contractor and Licensed Builder'.

8 REFERENCES

The following references include Singapore Standards, Codes of Practice, Circulars and Good Industry Practice Guidebooks

1. British/European Standard, BS EN 13964:2014 Suspended Ceilings – Requirements and Test Methods
2. Australian/New Zealand Standard, AS/NZS 2785:2020 Suspended Ceilings – Design and Installation
3. Singapore Standard, SS553: 2009 Code of Practise for Air-conditioning and Mechanical Ventilation in Buildings (formerly CP 13)
4. ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) Handbook
5. IHVE (Institution of Heating and Ventilating Engineers) Guidebooks
6. SMACNA (Sheet Metal and Air Conditioning Contractors' National Association) Manuals
7. Manufacturers Standardization Society, MMS SP-58-2018 Pipe Hangers and Supports – Materials, Design, Manufacture, Selection, Application, and Installation
8. Singapore Standard, SS 636:2018 Code of Practice for Water Services – Installation Requirements on Fixing (Formerly CP 48)
9. Singapore Standard, SS CP 52:2004 Code of Practice for Automatic Fire Sprinkler System – Design, Specification, Installation and Testing Requirements on Fixing
10. Singapore Standard, SS 608:2015+A1:2017 Code of Practice for Gas Installation – Design and Installation Requirements on Fixing (Formerly CP 51)
11. International Electrotechnical Commission (IEC) 60335-2-80: 2015 Household and Similar Electrical Appliances – Safety – Part 2-80: Particular Requirements for Fans, and to sub-clauses 5.7 and 5.8 of SS 360: 1992 or annex ZA of SS 655: 2020

12. Singapore Standard, SS 655: 2020 Safety of household and similar electrical appliances – Particular requirements for fans

13. Consumer Protection (Safety Requirements) Regulations Information Booklet, Enterprise Singapore 2021

14. Eurocode Standard, BS EN 1991 Actions on Structures

15. Eurocode Standard, BS EN 1993 Design of Steel Structures

16. Eurocode Standard, BS EN 1999 Design of Aluminium Structures

17. Eurocode Standard, BS EN 1090 Structural Steel and Aluminium

18. British Standard, BS 8539:2012 Code of Practice for Selection and Installation of Post-Installed Anchors in Concrete and Masonry

19. Construction Fixings Association Guidance Note – Procedure for Site Testing Construction Fixings

20. British/European Standard, BS EN 1504 Part 1 to 10 Products and Systems for the Protection and Repair of Concrete Structures

21. British Standard, BS 8210:2020 Code of Practice for Facilities Maintenance Management

22. Design for Maintainability (DfM) Guide, BCA

23. BCA Circular: 18 Mar 2015 – Advisory on Good Practices for Design and Installation of Suspended Ceiling Works

24. BCA Circular: 30 Nov 2018 – Reminder on Good Practices for Design and Installation of Suspended Ceiling Works

25. BCA Circular: 17 Mar 2021 – Advisory on Good Practices for Design and Maintenance of ACMV Fixtures

26. BCA Circular: 1st Jun 2021 – Advisory on Good Practices for the Inspection and Maintenance of Suspended Ceilings

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