



## CHAPTER 5

# MAINTENANCE ASPECTS

### 5.1 General

The facade, being the essential architectural and functional component of a building, requires utmost attention on its long-term maintainability, reliability and operability. Any negligence considering the maintainability during the planning, design, procurement, construction, and start-up of facility can lead to increased life-cycle operation and maintenance costs, and expensive maintenance retrofits. Maintainability refers to the probability that a failed item will be restored to operational effectiveness within a given period of time, when the repair action is performed in accordance to the prescribed procedures [1]. It represents a goal-attainment evaluation that may assure better long-term performance of buildings throughout their life cycles in three aspects; end-user expectations, operation and maintenance [2–11].

Due to the fact that maintenance cost of a building during its service life constitutes a large proportion of the total costs, it is essential to give adequate considerations to the whole-life performance of a building. Table 5.1 shows an example of the factors to be considered at the design, construction and operational stages of a building facade in order to achieve maintainability.

### 5.2 Cleaning Stains

This section will briefly describe simple cleaning methods on stained facades.

**Table 5.1.** Maintainability of facade — Performance matrix.

COMPONENT : FACADE	<i>Integrity</i>	<i>Acoustics</i>	<i>Lighting</i>	<i>Thermal</i>	<i>IAQ</i>	<i>Visual</i>
Component detail :						
<b>DESIGN AND CONSTRUCT</b>						
<b>1. Design</b>						
a. Buildability (BDAS)						
b. Upgradability						
c. Retrofitability						
d. Accessibility						
<b>2. Detailing</b>						
a. Interface						
b. Joints						
c. Drainage						
d. Openings						
e. Penetration						
f. Fixtures						
<b>3. Materials</b>						
a. Durability						
b. Life cycle						
c. Repairability						
d. Replaceability						
e. Sustainability						
<b>4. Construction</b>						
a. Prefabrication						
b. Workmanship						
c. Warranty						
d. Commissioning						
<b>OPERATIONAL</b>						
<b>1. Cleaning</b>						
a. Material						
b. Labor						
c. Access						
d. Down time						
e. Loss in productivity						
f. Frequency						
<b>2. Energy</b>						
<b>3. Inspection</b>						
a. Frequency						
<b>MAINTENANCE</b>						
<b>1. Repair</b>						
a. Diagnostic						
b. Materials						
c. Labor						
d. Down time						
e. Loss in productivity						
f. Frequency						
<b>2. Replace</b>						
a. Displacement-neighboring components						
b. Materials						
c. Labor						
d. Down time						
e. Loss in productivity						
f. Frequency						

### 5.2.1. Exposed Brick and Concrete Walls

Bricks are usually durable materials that age gracefully and require minimal cleaning. Nevertheless, dirt staining and efflorescence do cause bricks to lose their aesthetic value over time [12]. Table 5.2 shows some cleaning methods for brick walls of various conditions [12].

Dirt stains and biological growth could be water blasted to remove them from the brick wall. Efflorescence has to be brushed or scraped off from the surface whenever the salts appear. Brick masonry can generally be cleaned with chemicals in conjunction with water rinsing. Acidic

**Table 5.2.** Cleaning and maintenance of brick wall [12].

Condition of Brick Wall	Cleaning Method
<i>Dirt on brick</i>	
Clay bricks	Organic stains should first be removed with detergents before other chemical agents are used. If the texture of the brick is rough, pressurised water cleaning (< 700 psi) may be used in conjunction with light brushing with fibre brushes, but taking care not to initiate efflorescence.
Glazed bricks	Surface soiling may be cleaned using a water rinsable neutral liquid detergent. Soiling beneath cannot be removed.
Biological staining	Removed by brushing with fibre brushes or in conjunction with water spray or chemical cleaning using a solution of muriatic acid.
Green/buff or cream coloured stains from Vanadium salts (newly erected brickwall)	Scrub with a solution of 10% hydrochloric acid containing detergent at 0.1% of the total acid solution and wash thoroughly with water. Leave the wall alkaline by washing with potassium hydroxide (50g/L).
Paint on wall	May be removable with water rinsable paint removers to BS 3761: 1995. Alkaline-based agents may also be useful. The surface should be rid of residual resins and pigments by washing with a high-pressure water lance.
Walls with efflorescence	Should be allowed to weather away over time. May be removed by dry brushing with a stiff bristle brush and rinsing with water. The residue should not be allowed to re-enter the brickwall at lower levels. Chemicals should not be used.
Walls with lime stains	Washing with dilute acid. The wall should be wetted with water before the acid is brushed on. Upon removal of the stains, the wall must be rinsed clean with water again.
Iron and manganese stains (light brown to black)	Chemical cleaning using 5% or 10% hydrochloric acid or painting the stains over with oxalic acid solution (120g/L).



cleaners containing dilute mineral acids such as hydrochloric, hydrofluoric, phosphoric and/or organic acids such as acetic and citric acids are used to remove heavy soiling from most brick masonry walls. The cleaning process involves applying the diluted cleaner to the pre-wetted surface and allowing a short dwell period. Chemical and soiling residues are removed by pressure water rinsing. The use of acid should be avoided in cases when steel accessories are incorporated in the brickwall. Bricks with high iron content may also be reactive to acids. Sometimes alkaline cleaners are used to remove soiling on brick surfaces, but the type of chemical cleaner should be selected with care, and then tested on small areas before it is used to clean the whole area. Certain chemicals may cause staining on some types of bricks. Soft bricks are particularly vulnerable to damage from aggressive cleaning methods. Cleaned bricks should be coated with a water repellent sealer to prevent bricks from getting wet [12–14].

If staining affects a large portion of a facade, it may be more economical to paint over the brick surfaces as shown in Figs. 5.1 and 5.2.

Exposed concrete is prone to staining due to surface irregularities [15]. Regular cleaning once or twice a year, with high-pressure water jet or a non-toxic and mild acidic-based solution is required to keep the building from staining [12–14]. Stains caused by rain that washes the dirt and dust, and algae growth are generally repairable by simple washing and scrubbing at the stained area (Table 5.3) [16, 17].

### **5.2.2. Natural Stone**

Natural stones may be generally classified into two general categories based on its composition: siliceous or calcareous. The former tends to be more durable and relatively easy to clean with neutral cleaning solutions (Fig. 5.3). The latter is sensitive to acidic cleaning agents and requires cleaning with specially formulated stone cleaners.

Natural stones are basically porous and they absorb spills and stains if left untreated. Sealers with repellency properties against weathering and ultra-violet rays may be considered to minimise cleaning work.



Figure 5.1. Painting over a brick wall.



Figure 5.2. Painted brick wall.

**Table 5.3.** Cleaning and maintenance of concrete wall [16, 17].

Condition of Concrete Wall	Cleaning Method
Atmospheric soiling	Low-pressure water washing from top down. High pressure water jets should not be used as it may drive the stain further into the concrete. If insufficient, it could be supplemented by the following in order: brushing with a soft brush, a mild soap, a stronger soap, ammonia or vinegar.
Severe soiling	<p><u>Chemical cleaning</u></p> <p>Ammonium hydroxide, sodium hypochlorite or hydrogen peroxide may be used with dilution. The surface should be flushed with water before and after washing to prevent etching by acidic agents. Chemicals containing salts may damage concrete due to adverse reactions.</p> <p><u>Mechanical cleaning</u></p> <p>Involves power tools such as grinders, buffers, chisels, brushes or steam/ flame cleaners. Concrete may be removed along with the stain to result in a roughened or uneven surface.</p> <p>Organic stains that cannot be removed with solvents may be burnt off with flame cleaners. However, the heat may cause part of the concrete surface to scale off.</p>
Biological staining	Heavy growth should be removed by brushing with stiff fibre brushes, wooded spatulae, scrapers or a low-pressure water lance. Biocide should be applied to inhibit further growth.
Oils stains	May be removed by applying an emulsifying or degreasing agent. Deep stains should be poulticed with white spirit or trichloroethane. The deposits should be then removed with hot water pressure lance or with steam.
Walls with efflorescence/ lime stains	<p>Usually disappears itself by natural weathering.</p> <p>May be removed by washing with a 5% solution of hydrochloric acid. Alternatively, brushing with soft compact brushes and sponging the residual powder away may be more effective since excessive wetting with water may initiate further efflorescence formation.</p>



**Figure 5.3.** Cleaning of facade consisting of glass and natural stone.

Cleaning by water coupled with scrubbing or high-pressure water jet could effectively remove most of the stain from stone cladding surfaces (Table 5.4) [12]. Cleaning should begin at the top so that excess water can run down and pre-soften the dirt below. Acidic cleaning agents should not be used for granite as they may attack the pyrite (iron sulphide) which is inherent in granite to result in brown stains. It is also not proper to use cleaners that contain petroleum (which may change the appearance of the stone) or products that contain other acids or abrasives that may scratch the surface [18, 19].

### **5.2.3. Tiles**

Table 5.5 summarises the common staining problems with external tiled wall and shows examples of maintenance strategies [20, 21]. The dirt stains will be more concentrated at the mortar joints since mortar has a higher porosity and absorbs water quickly to leave behind dirt particles within the joints. If a sealant is used at movement joints and the sealant

**Table 5.4.** Cleaning and maintenance of natural stone wall [12].

<b>Condition of Natural Stone Wall</b>	<b>Recommended Cleaning Method</b>
<b>Unpolished Granite</b> (Atmospheric Soiling)	Chemical/ abrasive methods needed. Agents containing hydrofluoric acid may be useful. Alternatively, use alkaline cleaners followed by neutralisation with weak organic acid.
<b>Polished Granites</b> (Atmospheric Soiling)	<p>May be removed with non-ionic soap and scrubbing in water. Surfaces should be thoroughly rinsed and wiped dry to prevent water spotting.</p> <p>* Visual inspection every five years. If necessary cleaning, repointing and surface repairs in accordance with BS 6270:Part 1</p> <p>* Strong acidic cleaning agents should not be used as it attacks pyrite (iron sulphide) inherent in granite to result in a brown stain.</p> <p>* Apply silane-based impregnating agent every 5 years to seal stone against dirt and pollutants.</p>
<b>Marble</b>	
Water soluble sooty particles	Washing with small quantities of water. Soften the dirt by hand-spraying, followed by scrubbing with bristle brush and hand-spraying to remove dirt.
Metallic, oil or grease stains	<p>Remove with liquid detergents. If stains persist, use acid or alkali based agents.</p> <p>* Acids, phosphorus, chlorine or scouring powder should not be used. Hard water will encourage discolouration, particularly if iron is present, and cause the build-up of insoluble salts. Re-polishing may be required on a regular basis.</p>
<b>Sandstone</b>	Chemical cleaning using hydrofluoric acid and orthophosphoric acid-based agent. Or dry air abrasion cleaning using mineral slag abrasive agents.
<b>Stones with Efflorescence/ Lime Stains</b>	Remove by brushing with fibre brushes or in conjunction with water spray or chemical cleaning using a solution of muriatic acid.
<b>Biological Staining</b>	Remove by dry brushing with wooden scrapers or bristle brush or by high pressure water jetting. Surface should then be treated with anti-fungicidal wash.

\* denotes general notes



**Table 5.5.** Cleaning and maintenance of tiled wall [20, 21].

Condition of Tiled Wall	Cleaning Method
Ceramic Tiles	General cleaning by wiping with wet cloth or scrubbing with sponge. For heavier soiling, use a mild detergent solution and leave it on the surface for 5 minutes before scrubbing lightly with a brush.
Mosaic Tiles	General cleaning by wiping with damp sponge mop. For heavier stains, cleaning agents can be supplemented with brushing. Pressure blasting can also be considered to wash away dirt trapped at the joints.
Efflorescence/ Lime Stains	Removed by dry brushing or with water and a stiff brush. Heavy efflorescence or lime stains may be removed with mineral acids such as hydrochloric, sulphuric and nitric or other organic acids. Wet the surface well before and after the solution is applied.
Mildew	Remove with a dilute solution of ammonia or bleach. Concurrent scrubbing may be needed.
Biological Staining	Use a weak acid such as vinegar.

fails and becomes sticky, it will hold dirt until it rains. Dirt is then deposited in streaks down the building, emanating from that point [19]. Depending on the tiles used and the extent of staining on the surface, cleaning agents can be selected according to the state of staining. Care should be taken during the selection of cleaning agents as abrasive agents can easily etch the tiles, making them more vulnerable to dirt. Tiles used should be glazed and of darker colour to mask excessive dirt stains.

#### 5.2.4. Metal

The appropriate type of cleaning method used is determined by the degree of soiling, the size, shape and location of the surface to be cleaned. The cleaning specifications should be followed closely with respect to the frequency and method of cleaning (Table 5.6) [22, 23].

It is preferable to clean metal surfaces in the shade as possible chemical reactions on hot metal surfaces may be highly accelerated and

**Table 5.6.** Cleaning and maintenance of metal wall [22, 23].

Condition of Metal Wall	Cleaning Method
<b>Aluminum</b>	
<b>Anodic Coating</b>	
Lightly soiled	Flush surface with water at moderate pressure. Use mild detergent, and brushing or sponging concurrently if necessary.
Heavy soiling	Scrub with a nylon-cleaning pad wet with surface protective material. Rinse surface with water and wipe dry with a chamois, squeegee or lint-free cloth or air dry.  Power cleaning tools (e.g. air-driven reciprocating machine fitted with abrasive pads) and mild detergent can also be used. Direction of travel of machine with respect to geometric configuration of the surface being cleaned should be noted.
<b>Powder Coating</b>	
Lightly soiled	Flush surface with water at moderate pressure. Use mild detergent, and brushing or sponging concurrently if necessary.
Heavy soiling	Mild solvent (eg. mineral spirits) may remove grease, sealant or caulking compounds.  Dried concrete stains can be removed with diluted muriatic acid (under 10%). Vigorous rubbing with non-abrasive brushes or plastic scrapers may be necessary  * Some solvents may extract materials from sealants and cause staining or damage the sealant. * Abrasive cleaners containing ketones, ethers or alcohols and steel wool should not be used. * Coatings may require re-decoration after 10–15 years. * Clean polluted/marine areas every 3 months, other areas every 6 months.
<b>Steel</b>	
Dirt and pollution	May be removed by rinsing with water and mild detergent, then scrubbing in the direction of the grain with soft cloths, sponges, fibrous brushes, or plastic pads. Abrasive actions should however be minimised since these may scratch the finish. Steel wool/brushes will causing pitting and should not be used.
Chlorides	Remove with warm water.
Fingerprints, grease, oil	Remove with a combination of water, mild detergent, and mineral spirits.

Table 5.6. (Continued)

Condition of Metal Wall	Cleaning Method
Iron stains (from bolts, screws, etc)	Remove rusty elements and immerse them in nitric acid.
Graffiti (Water-soluble inks)	Use warm water and a non-ionic detergent and rinsing with water.
Other inks and paint	Use a combination of water, non-ionic detergent and mineral spirits and rinsing with clean water.
Lead pencil markings	Remove with an oily cleaner such as paste wax.
Weld stains	Remove with mild abrasive cleaner in paste form and water.
Corrosion products	Remove with warm water, detergent, and plastic pads. If severe, mechanical methods (e.g. grinding or sandblasting) may be appropriate. Surface refinishing with fine abrasives to restore to original.
	* Clean polluted/marine areas every 3 months, other areas every 6 months.
	* Annual inspection and maintenance in accordance with BS 5427: Part 1, Table 9.
<b>Biological Staining</b>	Fungicide. Leave on wall for up to 7 days. All traces of the fungicide and effluent should be removed and the surfaces thoroughly rinsed with water.

\*denotes general notes

non-uniformity can occur. For slightly soiled surfaces, cleaning should be done with water and some detergent. It should be completed by carefully rinsing with clear water and wiping with a soft and absorbent cloth. For moderately soiled surfaces where the soiling cannot be removed by normal detergents, it is recommended that products which are developed especially for this purpose be used. These products may contain detergents and very light abrasive materials. For very dirty surfaces where the dirt is very stubborn, it may be necessary to apply the same means as mentioned above but with the use of synthetic pads.

There are many ways to clean metals, from using plain water to harsh abrasives. The mildest possible method should be used, particularly for



anodised aluminum. The following cleaning materials and procedures are listed in ascending order of harshness. The mildest treatment should be tried on a small area and if the results are not satisfactory, the next method may be examined.

- Plain water.
- Mild soap or detergent.
- Solvent cleaner, e.g. kerosene, turpentine, white spirit.
- Non-etching chemical cleaner.
- Wax-based polish cleaner.
- Abrasive wax.
- Abrasive cleaner.

The procedure for cleaning should begin with applying the cleaning solution only to an area that can be conveniently cleaned without changing position. The surface should be thoroughly rinsed with clean water before applying the cleaner. Cleaner rundown should be minimised on the lower portions of the building and such areas should be rinsed as soon and as long as it is practical. The metal panel should be dried with a clean cloth to prevent streaking. There should be no concentration of the cleaner at the bottom edges of the aluminium. If abrasives are used then the appearance of the metal finish may be altered. If there is a grain in the finish then cleaning should always be with the grain. When all other methods fail it may be necessary to resort to heavy-duty cleaning. This involves the use of cleaners containing strong etching chemicals or coarse abrasives (Fig. 5.4) [22–24].

Cleaners containing strong organic solvents will have a deleterious effect on organic overlay coatings, but not on anodised aluminium. However, the possibility of solvents extracting stain-producing chemicals from sealants and affecting the function of the sealants must also be considered [19].

Depending on the causes of staining, different measures can be taken to mitigate its influence. In most cases, only cleaning work is needed. However, if the staining is caused by the degradation of cladding materials and sealant, the replacement of the defective element is needed.



Figure 5.4. Cleaning aluminum panels with a scrub.

### 5.2.5. Glass

Table 5.7 shows the common maintenance methods for glass facades [25, 26]. The procedure for cleaning glazed surfaces begins by wringing a cloth, sponge, or chamois until it is almost dry before wiping the glass surface (Fig. 5.5). The wet surface is then dried with newspapers, paper

Table 5.7. Cleaning and maintenance of glazed surfaces [25, 26].

Condition of Glass Wall	Cleaning Method
Soiled and greased glass	Wring out a cloth, sponge, or chamois almost dry before wiping the glass surface. Use an alkali, such as ammonia or baking soda or washing soda. Dry the wet surface with newspapers, paper towels, window wipes, or a chamois. Avoid washing windows in direct sunlight because they tend to streak and are more difficult to clean.
Hard water deposits and soil	Use a weak acid such as vinegar (a strong acid would etch the glass). Avoid cleaning glass under direct sunlight as they tend to streak.



**Figure 5.5.** Wiping glass surface with chamois.

towels, window wipes, or a chamois. Avoid washing windows in direct sunlight because they tend to streak and are more difficult to clean.

### ***5.2.6. Plaster-and-Paint Surfaces***

Regular inspection of the coated surfaces is important in determining the seriousness of stains and the frequency of cleaning required.

The use of alticides, washing and repainting of walls regularly (every few years) can keep stains and biological growth at bay. Care must be taken on painted surfaces as sunlight can actually penetrate through one or two layers of paint and cause growth underneath instead, and eventually break through the new layer of paint [27].

Stained plaster-and-paint walls are usually cleaned by washing and scrubbing (Table 5.8) [28, 29]. However if the stains are too serious and widespread, it is more appropriate to remove the affected surface coating, sand, clean and redo the coating.

**Table 5.8.** Cleaning and maintenance of painted wall [28, 29].

Condition of Painted Wall	Cleaning Method
Oil paint	Wash with water and a non-abrasive weak alkaline detergent (e.g. hand dishwashing liquid). Stronger solutions may remove some of the paint.  Walls should be cleaned upwards commencing from the bottom and in a sideways manner. This prevents staining of the surface by water.
Semi-gloss paints	Wash with a non-abrasive weak alkaline detergent using less water. Hard-bristled brushes should not be used.  Walls should be dry brushed regularly and washed only once a year.
Gloss paints	Water and a weak detergent may remove atmospheric dirt on the surface. Rinse with clean water after washing.
Water paints	Small build-up of dirt may be removed using light sponging with a weak detergent and clean water. Excessive water should not be used as it may damage the finish. Regular cleaning by dry brushing is recommended.

### 5.3 Facade Access Systems

A facade access system is required for inspection, maintenance and cleaning of tall buildings. Such systems can be expensive to provide and maintain, difficult to design, dangerous to use and awkward to operate especially for buildings with high irregularity in shape (Fig. 5.6). The facade access system shall be designed, fabricated and installed to satisfy the following minimum requirements [11, 30, 31]:

- It should have a relatively long design life of between 10 to 25 years.
- It should withstand all loadings (wind, dead and live) as stipulated by local codes and specifications.
- It should provide workers with easy and safe access to all areas of the facade for all cleaning, repair and replacement works.
- When in operation, it should not bring about disruptions to tenants' activities or cause damage to the facade.



**Figure 5.6.** A specially designed gondola to reach inaccessible areas.

- It should be designed to provide maximum coverage to the facade including clearing protrusions on the facade such as sunshades and hence fulfil the required cleaning cycle.

The provision of facade access systems should be carried out in strict accordance with recognised codes and standards.

#### **5.4 Codes and Standards**

Relevant codes and standards pertaining to the use of equipment and cleaning of the external facade that ensure the safety and health of maintenance personnel are:

##### ***International Codes and Standards:***

- **BS 7883:1997** Code of practice for application and use of anchor devices conforming to BS EN 795.





- **BS EN 795:1997** Protection against falls from a height. Anchor devices. Requirements and testing.
- **BS 5973:1993** Code of practice for access and working scaffolds and special scaffold structures in steel.
- **BS 6037:1990** Code of practice for permanently installed suspended access equipment.
- **BS 1139-1.2:1990** Metal scaffolding. Tubes. Specification for aluminium tube.
- **BS 1139-2.1:1991, EN 74:1988** Metal scaffolding. Couplers. Specification for steel couplers, loose spigots and base-plates for use in working scaffolds and falsework made of steel tubes.
- **BS 1139-2.2:1991** Metal scaffolding. Couplers. Specification for steel and aluminium couplers, fittings and accessories for use in tubular scaffolding.
- **BS 1139-3:1994** Metal scaffolding. Specification for prefabricated mobile access and working towers.
- **BS 1139-4:1982** Metal scaffolding. Specification for prefabricated steel splitheads and trestles.
- **BS 1139-5:1990, HD 1000:1988** Metal scaffolding. Specification for materials, dimensions, design loads and safety requirements for service and working scaffolds made of prefabricated elements.
- **BS 6399-2:1997** Loading for buildings. Code of practice for wind loads.
- **BS EN 1808:1999** Safety requirements on suspended access equipment. Design calculations, stability criteria, and construction. Tests.
- **BS EN 280:2001** Mobile elevating work platforms. Design calculations. Stability criteria. Construction. Safety. Examinations and tests.
- **AS/NZS 4488.1:1999:** Industrial rope access systems — Specifications.
- **AS/NZS 4488.2:1997:** Industrial rope access systems — Selection, use and maintenance.



***Singapore Codes and Standards:***

- SS 210: 1979 Industrial safety belts and harnesses.
- SS CP 14: 1996 Code of practice for scaffolds.
- SS CP 20: 1999 Code of practice for suspended scaffolds.
- SS 280: 1984 Frame scaffoldings.
- SS 311: 1994 Steel tubes and fittings used in tubular scaffolding.
- The Factories (Building Operations and Works of Engineering Construction) Regulations 1998.

**5.5 Means of Access**

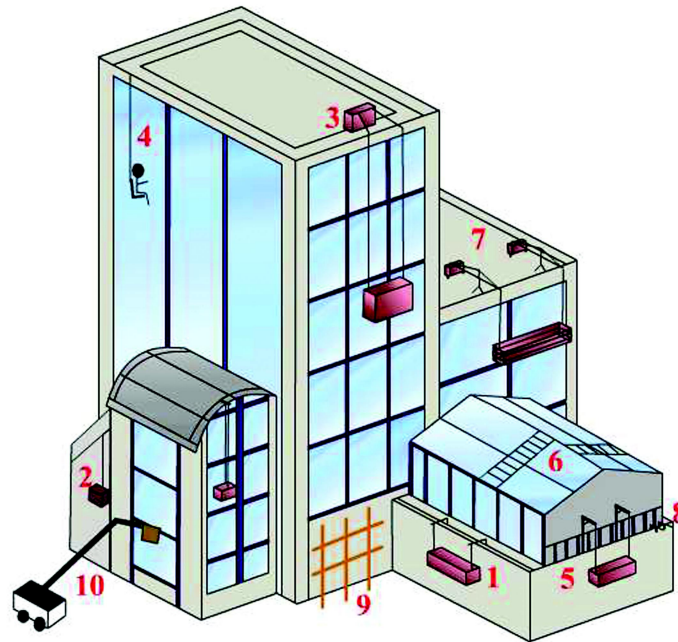
A building facade's maintenance expenditure is influenced by the building's shape and form. The form of buildings that have been chosen may have a bearing on the method of maintenance. The various types of facade access systems are shown in Fig. 5.7.

***5.5.1. Permanent Systems***

A permanent access system is a planned installation which is implemented at the construction stage. These access systems are usually used for maintenance of facades, window cleaning and building inspection for long-term purposes [32–35]. They can be classified as shown in Table 5.9.

Permanently installed gondolas are dedicated to a specific building or structure. These systems are provided to facilitate regular inspection, maintenance and cleaning purposes. As it is specifically designed for each particular building, it introduces an element of safety in external access engineering which is unsurpassed. For high-rise buildings, gondola systems are more frequently used. This system is usually used due to its low installation cost. Nevertheless, this type of system does involve safety disadvantages. It is dangerous when cleaning is done under strong wind conditions.

A permanently installed gondola consists of a platform suspended from a suspension rig. The suspension rig is usually a trolley unit with a



Permanent Access system	Temporary access system
1: Trolley unit/ powered travelling davits	7: Counterweight suspended beam
2: Mono rail system	8: Parapet clamps
3: Traversing trolley	9: Scaffolding
4: Personal units	10: Booms
5: Fixed davits	
6: Travelling ladders	

**Figure 5.7.** The various types of access systems, both permanent and temporary.

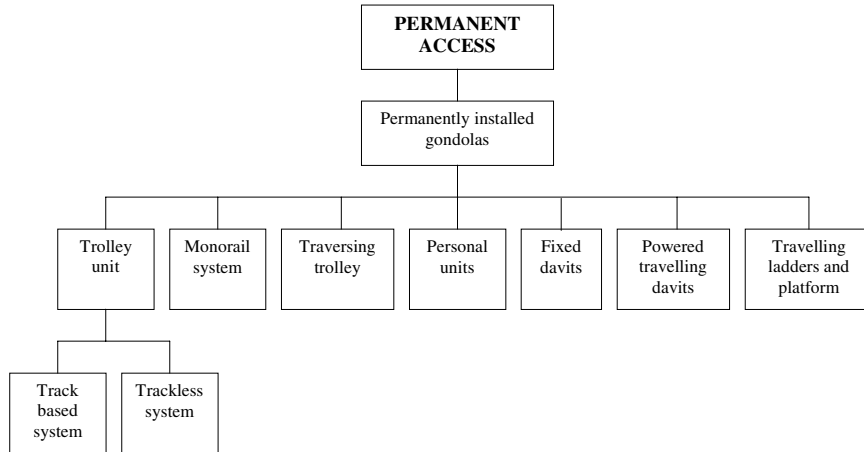
hoist, operating either on rails or on a suitable surface such as a concrete track.

#### 5.5.1.1. Trolley Unit

The trolley unit is also known as the Building Maintenance Unit (BMU), or a roof-car. It is a machine equipped with an integrated lifting hoist, a jib and a cradle and running on the roof of a building (Fig. 5.8).



**Table 5.9.** Classification of permanent access systems.



**Figure 5.8.** A trolley unit suspended from a lifting hoist running on the roof.



It allows complete access to all external parts of the building at the touch of a button. Its movements are controlled safely from the push-button control panel. Access to the cradle and to its garage is from the roof and the operator does not have to assemble or dismantle anything. The built-in safety devices control and monitor the operations of the unit to ensure safety.

The most commonly used trolley unit system used in the region are:

- Track based system (Fig. 5.9).
- Trackless system (Fig. 5.10).

#### 5.5.1.2. Monorail Track

This system is used mainly for recessed or overhanging facades, buildings with sloped roofs and for cleaning the inside of a glazed atrium.

The monorail track follows the line of the facade closely, with cradles suspended from manual or powered trolleys to reach the various points of the facade or roof. It also permits access to inclined roof sections (Figs. 5.11 and 5.12).



(a)



(b)

**Figure 5.9.** Trolley unit system running on tracks.



(a)



(b)

**Figure 5.10.** Trackless trolley unit running on wheels.



**Figure 5.11.** Monorail track along the line of the facade.

### 5.5.1.3. *Traversing Trolley*

Depending on the design of the building or the architect's requirement, a traversing trolley may be considered for horizontal traversing on unreachable areas (Fig. 5.13).





(a)



(b)

**Figure 5.12.** (a) Special support brackets anchored to the facade and; (b) anchored to the roof.



**Figure 5.13.** Traversing trolley along glazed.