

# Identifying the Critical Components to Extend Concrete Flat Roof Service Life in Equatorial Climates: A Review

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**Abstract:** *The concrete flat roof has its own advantages and preferred of designers to be selected as the building roof. The concrete flat roof has a variety of functions for all room space can be fully utilized either at the bottom and the top of the roof. There are also buildings that incorporate design slope roofs and flat roofs that keep services and facility equipment in the flat roof area. Building owner and designer will benefit from identifying the seven key factors to extend concrete flat roof service life, especially in equatorial climate. Building owners and design team should consider hot and humid condition throughout the year during the design and construction stage. Although the roof system selection process is often driven by client budget, aspects of the durable, economical and long-lasting roof also need to be given attention. The review has been carried out based on secondary sources that outline the flat roof performance as the keywords. Surface profile, materials, maintenance schedule and current usage of concrete flat roof is inspected and analyzed. To extend the service life of concrete flat roof in equatorial climates, seven critical components are identified and should be considered in the design and development that consists of the slope, drainage, waterproofing, material durability, constructability, maintenance, and use and occupancy.*

**Index Terms:** *Building survey, condition, flat roof, building defects, equatorial climate.*

## I. INTRODUCTION

The roof is the main protection component of a building. There are two types of roofs, namely, pitch roof and flat roof. Compared with the pitch roof, the flat roof has a slope that is less than 10 degrees; thus, many activities can be performed on top of it. However, such advantage comes with one common problem: water related problems. This is a serious problem that can lead to other defects on a building. For example, water ponding on lightweight flat roof can cause collapse if the applied load is excessive. Moreover, water ponding is the main source of moisture on a flat roof made of concrete slab.

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In recent years, maintenance work to concrete flat roofs of multi storey buildings has increased significantly. Even a small percentage, the concrete flat roof maintenance need to be due attention.

Flat roof will receive direct sunlight throughout the day compared to slope roof. In equatorial climate with hot and humid condition throughout the year and relatively high annual average rain intensity in 250 cm (98 inch) yearly and with average temperature is 27 °C (80.6 °F), the cause of problem that mostly associates with the concrete flat roof is the insufficient slope gradient, roof drainage clogged and not smoothly flow, water proofing to building failure or damages, low grade and not quality materials, a difficult constructability, no maintenance or poor maintenance schedule and abuse in use and occupancy. These critical factors lead to short life cycle of concrete flat roof, not durable, uneconomical and burst of client budget and will caused inconvenience to the occupants. Among the most common problem of flat roof is the water ponding related issue.

Roof drainage issues including inadequate drains, scuppers and slopes [1]. These factors are mostly related to human factor, which are design errors or construction errors. A proper roof drainage is often not fully addressed in building design due to a mixture of overlapping design disciplines between architect, plumbing consultant and structural engineer [1]. Sometimes, the segregation of these disciplines causing errors during the process of information delivering and sharing.

However, roof drainage problems also cause by external factors that cannot be control by human. For example, water ponding occur on flat roof when the regular rainwater drains are fully or partial blocked by leaves, feathers or other materials [2]. This occurrence may happen even if there are no design errors. For a tropical country like Malaysia, rainfall occurs throughout the year regardless of season. Thus, those external factors must be monitor to avoid water ponding problem by performing routine cleaning works.

Vambersky [3] pointed that declining importance of coordination, checking, control and site supervision is one of the factors that cause of failures due to rainwater ponding. Later, De Silva and Ranasinghe [4] found that the level of maintainability of a typical flat roof is only 51%. Therefore, clear that poor maintenance of the roof drainage system is one of the causes of roof collapses [1]. Thus, flat roofs need immediate attention in terms of maintenance [4] especially to control water ponding problems.



In order to detect all these defects, the building inspection is an important task [5]. This paper first provides an overview of the critical components that are able to extend the service life of concrete flat roof in equatorial climate. Next, the building condition survey is going to be carried to the building under case study.

## II. METHODOLOGY

The main approach in identifying the critical components as to extend the service life of flat roof is by conducting a review based on secondary sources. The literature search covers both journals and proceedings documents. The search keywords used are flat roof, building defects and roof in equatorial climate. The Google search engine is adopted in a first place, before getting the full documents via relevant database such as Emerald and Science Direct.

## III. SEVEN CRITICAL COMPONENTS OF FLAT ROOF

Concrete flat roof is the most cost-efficient as all room space can be fully utilized at the bottom and top of the roof. This style enables roofing panels provide sufficient space for building services and outdoor recreation facility or use as roof gardens and swimming pool. Applying a tough waterproofing membrane forms the ideal substrate for green roof planting schemes. In many areas, especially where unusual or gable roof space is limited, a flat roof can be utilized as living space, with a fully insulated, bathroom, living room and bedroom. In third world countries, the peak of the roof as is commonly used as a dry bar, for storage, as well as a place to raise livestock. Other uses include helipad, recreational areas (such as tennis courts), and restaurant outdoor seating. By considering seven factors (Figure 1) outlined in this paper, building owners and designers will consider the selection of a flat concrete roof and able to face the challenges of equatorial climate, with simple construction and maintenance in mind.

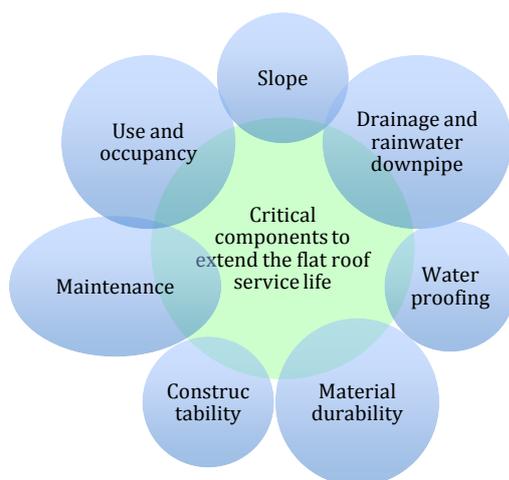


Fig. 1 Critical Components to Extend the Flat Roof Service Life

### 1. Slope

The slope of concrete flat roof also plays an important role in ensuring the flat roofs dry. Refer to British Standards BS [6], the relevant codes of practice for flat roofs

including BS6229 – Flat roofs with continuously supported coverings, BS8217 – Re-inforced bitumen membranes and BS8218 – Mastic asphalt roofing, clearly indicate the requirement to design falls onto flat roofs. In summary, the following criteria's would apply to flat roof designs for rainwater drainage: 'Flat Roof': Defined as a flat roof with a minimum finished fall of 1:80, 'Completely Flat Roof': Defined as a flat roof with a fall of less than 1:80 and 'Failed Roof': Defined as a flat roof with a backfall those results in excessive rainwater ponding.

While refer to the Building Officials and Code Administrators BOCA in the United States requires a minimum roof slope of 1/4 inch per foot or about 2% (BOCA 1999) [7]. The National Roofing Contractors Association (NRCA) emphasize on having proper drainage system and acceptable level of gradient (roof surface slope that easily allows the rainwater to discharge). One important criterionis free from water ponding scenario after 48 hours of normal raining downfall [8]. Water flow in excess of 48 hours is considered to have failed.

### 2. Drainage and rainwater downpipe

Roof drainage is also important to keep in mind when designing a building. Drainage will cooperate with the slope of the roof so that rain water, water from human activities, or water from building services equipment can be drained as soon as before 48 hours [9, 10]. Delays to drain water from the roof in a set time can be considered drainage is not functioning. This failure is usually caused by drainage blockage by debris, dust and wild plants that live in the roof area [11]. Stagnant water for a long time on the roof can cause the roof to be damaged and leaking.

The following elements are related to the flow of water is rainwater downpipe. Rainwater downpipe must always be free of any objects that may cause it to clog and fail to function properly. It should be designed and constructed with adequate and appropriate to the size of the concrete flat roof.

### 3. Water proofing

When choosing a concrete flat roof of the building as cover, it is imperative to choose the water proofing material as well [3, 12]. Bear in mind that this area is the most expose area to the weather all year long, especially on constant sunlight and rainfall simultaneously. The low quality of water proofing can easily had been tear off, perhaps less than a year after constructed. Apart from this, the design and construction stage need to be carefully observed. A good material from the manufacturer can become a fail one (and warranty void sometimes) due to mishandling of water proofing material during its construction period. A licensed installer is recommended in order to ensure the installation works smoothly and eventually will keep the water proofing long lasting. It is often found those economical factors (low market price) are not always the good practice. It might incur higher maintenance cost in the long run.

The reinforced cement concrete flat roof is typically done with ordinary concrete without using any additional mix to keep of the extra workability necessary for correct



placement and compaction of concrete through the tightness reinforcement. Occasionally compound waterproof material used in concrete. But often they are not used correctly or enough. Reinforced cement concrete flat roof is to serve two purposes. The first is weatherproofing slab to provide thermal insulation for the area underneath. Secondly, it is waterproof. This layer also provides the necessary slope for easy drainage of rain water [13].

#### 4. Material durability

Material durability must be hand in hand with the price. Careful attention and focus need to be more to life cycle costing, not a single installation cost alone. The saving at the early stage might not ended saving for the whole cycle of the building materials, and roofing materials is no exception. The element of budget, specification and durable must be balanced [14]. The insulation materials for instance, have to be effective and durable so that the repetition replacement after several years can be avoided. Typical roofing materials, if correctly installed, may last around 10 years or more.

Most concrete flat roof is a space to store equipment for the building services and facilities, making flat roofs are often accessible for routine maintenance and servicing of the equipment. Frequency of traffic on flat roofs generally has a significant impact on the service life of the roof. Roof designer is responsible for the selection of roof finishes that meet all endurance requirements. Durability requirements must meet specifications such as fire resistance, puncture resistance and tear, elongation, and weather ability mainly to equatorial climates. Other durability requirements may be imposed by the climate in which the roof is intended to serve, and the traffic on the roof needed to survive.

#### 5. Constructability

Constructability refers to the factors engaged in the construction of roofs on a particular building, taking into account the building location, altitude and type. The design process must take constructability into account in selecting methods such as the use of hot asphalt and cold adhesives. Normally a concrete flat roof constructed concurrently with other structures such as beams and columns. Construction method is similar to the construction of the concrete floor.

Safety during construction should also be emphasized because most of the roof structure is at high altitude from ground level. Use of heavy machinery may be involved when lifting building materials for concrete or waterproofing materials during the construction process concrete flat roof. Roof that serves to protect the building, equipment and its inhabitants of buildings to be constructed as perfect as possible and meet the specifications predetermined. Also advisable is to determine how the system described matches the expertise team builder who can undertake the construction.

#### 6. Maintenance

Maintenance is required for all types of roofs, especially concrete flat roof. Properly maintained and cleaning roof will have a longer service life and minimized cost of ownership. Maintenance practices in general are almost the same for all types of roof surface. Regular cleaning within certain interval point of time is needed, as to ensure it is not clogged on its horizontal surface. Using a waterproof layer of modified bitumen membrane type easily maintained

because of the damage the membrane surface could be seen and always clears.

Maintenance and cleaning of flat concrete roof requires little effort and sometime hard work. Compared with a steep roof, flat roof holds water and collect a lot of dirt, debris and sometime wild plants, which have been flown by the wind and easy to grow in a concrete flat roof [15]. In order to ensure that the roof is watertight and strong enough to hold available water, cleaning should be done regularly and implement a comprehensive inspection and periodic maintenance.

#### 7. Use and occupancy

Concrete flat roofs designed and constructed typically based on calculations and requirements at the time of the design. The selection of building and waterproofing materials are also selected based on use and occupancy requirements. Design and selection of materials that exceed the needs and functions will increase the cost of construction and uneconomical. Requirements of the residents or owners of buildings are aligned variable over time and current consumption needs. Changes in use and occupancy will result in damage to the flat roof if the current condition is not compatible with the new use. The decision to change the use and occupancy must take into consideration the current conditions and the possibility of a flat roof needs some modification to suit the new use and occupancy.

### IV. CONCLUSIONS

If building owners and designers is to recognize the seven major factors as outlined above, it can prolong the service life of the flat roof. This paper sets seven key factors of design and their effect on the service life of concrete flat roof. By using this design consideration, it can add slight performance to the whole life cycle of the roof, particularly in the equatorial climates area. Durable roof in the future will be designed using computer software and high-tech equipment, such as in virtual reality and Building Information Modelling (BIM). This simulation will help to predict all roof components to be more weather responsive. The climatic data is available for prediction of flat roof life cycle. Not to forget is the construction stage i.e. during the installation of the roof finishes, especially its water proofing materials. This is the first element that in contact with weather and whatever activity that take place on the roof surface. The protection during construction period and early days of occupancy is going to set a benchmark whether the flat roof and last long, or not.

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