



# The application of electromagnetic waves in monitoring water infiltration on concrete flat roof: The case of Malaysia



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## HIGHLIGHTS

- This paper provides a new idea on detecting water infiltration for concrete roof, which add on to the existing methods.
- It describes the potential use of microwave technology as an effective non-destructive tool to monitor and investigate leakage of concrete flat roof due to failure of membrane layer.
- Experiments performed utilized a sensor equipped with essential parameters that enable control to sensor angle, temperature and distance between object and sensor structure and designed to enable numerous measurements in real time.
- The study determined that microwave technology could be used to identify moisture content in concrete flat roof by analysing properties of the concrete roof and water.
- This proves to be an effective non-destructive method of determining leakage problems in concrete flat roof in real time before the defects become critical.

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## ABSTRACT

Roof leakages of high-rise buildings involving concrete flat roof design in tropical countries continue to be a serious problem. Currently, exiting methods of detecting potential leaks are mostly destructive to the building material. Although the method of detecting a defect using non-destructive measurement exists, current methods such as infrared thermography, metal detector and humidity meter have varying constraints in their application. This paper describes the potential use of microwave technology as an effective non-destructive tool to monitor and investigate leakage of concrete flat roof due to failure of membrane layer. This study was performed experimentally on flat room structures built for laboratory use and according to Malaysian flat roof concrete proportions standards. Experiments performed utilized a sensor equipped with essential parameters that enable control to sensor angle, temperature and distance between object and sensor structure and designed to enable numerous measurements in real time. The study determined that microwave technology can be used to identify moisture content in concrete flat roof by analysing properties of the concrete roof and water. This proves to be an effective non-destructive method of determining leakage problems in concrete flat roof in real time before the defects become critical.

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## 1. Introduction

Building roof leakage problems had often been reported by owners of high-rise buildings, especially in the tropical countries. Almost all of the buildings involved have concrete flat roof design. The roof leaks have been disturbing activities and space planning up to affecting the income from the rental of building space. There

are also buildings that had to be closed as a result of leaks that affect the safety of the user. Existing methods are not effective enough in detecting potential leaks. Most building owners taking a wait-and-see attitude until the building leaks occur. Thus, a method of effective monitoring is needed to address the issue. Non-destructive testing method is seen to have a potential to detect leakage problem at an early stage and other hidden defects before becoming critical. This paper describes the potential use of the microwave as a tool to monitor and investigate leakage of flat roof concrete due failure of membrane layer installed on the roof.

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Many building defects reported involves the quality of building materials as well as materials that are embedded [4]. Although the method of detecting a defect using non-destructive popularity this time, existing methods is rather limited. Of those approach adopted are infrared thermography, metal detector and humidity meter, which, have certain constraints. Because of the limit, some destructive test methods had been used to detect any anomalies involving the hidden flaw. This destructive approach will damage the other components of the building. Hence, there is a pressing need to enrich the method and use of non-destructive testing more effective and not damaging part of the building to another. Inline with that, microwave applications in detection of different materials properties are seen as having great potential to meet these needs.

### 1.1. Flat roof for Malaysia building

Building materials identified as one of the factors that contribute to the defects in buildings. Interestingly, the building materials for a building consisted of a several of basic materials such as plastic, metal, stone, glass and composite materials. The materials chosen should be able to stand in line with the whole lifespan of a building. It is reported that although the installation method of building materials carried out as per manufacturer's instructions, it still had contributing to the occurrence of defects within a building. In addition, the quality of the building materials that sometimes does not reach to required standard or functioning properly while the fast paced changes of the weather caused the materials performance declined significantly. For instance, a flat roof construction, membrane layer even installed by legitimate manufacturers or trained contractor, building owners often faced the problem of building defect and unsatisfactory performance that resultant in leakage of the roof a few years later [15]. In the market, there is also a layer of membrane that require special mixing ratio with other materials such as cement, chemical, mortar and so forth, which will respond when it exposed to the effects of climate change and erratic temperatures. Other building materials also having the same problem such as peeling of paint and finishes like tiles installed will also be falling and face problems because of the tile itself least adhesive and porosity [11].

Some of the building materials mentioned are in composite and embedded, which cannot be seen physically. For example, PVC water pipe buried in the wall or floor, steel reinforcements in the concrete and etc. When there are defects resulting from composite materials, it is hard to determine the substantial cause. For water pipe leaks or clogged pipes in the walls or floors, it is hard to determine the actual location and cause of the potential problem. Most of the building defects occur after the building was occupied and method to get information about it is limited. Most defects were architecture and structure [4]. Seeley [22] studied found that the problem of the defect caused by the workmanship is 35% while 12% come from the quality of materials used. Thus, there is a need for a non-destructive technique that is more efficient to be dealt with this problem, which is more effective and reduce costs.

It is the practice of concrete flat roof in Malaysia using rapid hardening concrete in-situ for ease of construction and maintenance in the future. Flat roof has gradient around 10 degrees in order to drain rainwater perfectly to tap in the gutter. This is important in order to avoid any water retention happens after rain, which could result in leaks. Obviously, the advantages of the use of concrete flat roof are it has a high compressive strength, thus it is suitable for rooftop access facilities as well as the ability to take the burden of life load. Reinforced concrete roof is also not easily suffering due to climate change. In Kuala Lumpur, the difference the weather throughout the day is rather significant and could achieve a difference of temperature above 10 °C in a day [24]. Thus, the

concrete roof must be able to withstand the temperature difference and not easily cracked and damaged.

In order to avoid water infiltration into buildings through the flat roof for skyscrapers, a thin layer of bitumen or membrane layers used to cover the concrete roof. In many cases, installation of membrane depends on the manufacturer's instructions. In normal circumstances, within 24 h the installation should be completed for the membrane layer to avoid any failure in the future [24]. It is however depending on the weather conditions during the installation process performed. A layer of membrane needs to be installed on the roof of the concrete cleaning and free from any debris or foreign objects. If the membrane installed on the concrete that has not been completely dried will trap moisture, which in long term can cause the effects of rust on the reinforcement and cracks in the concrete.

In Malaysia, most flat roof for high-rise buildings used for the space of building services equipment. Usually, a roof area is more than adequate to provide spaces for services equipment such as cooling tower, domestic, fire and air-conditioning water tanks. Hence, the design and installation of the roof concrete need to absorb any vibration generated by the equipment; as well as membrane layer to avoid any leakage in the future.

### 1.2. Malaysia climate

The weather in Malaysia is categorised as equatorial and located in tropical areas. Various conditions of temperature and rainfall throughout the year in which indirectly effect on the durability of materials used in a building. Malaysia has an average rainfall of 2500–3500 mm per annum with the Sabah recorded the highest reading. The annual average temperature readings recorded between 20 °C and 30 °C with relative humidity between 78% and 90%. The weather was much depends on the wind direction from the southeastern and southwest monsoon during the year. The humid condition throughout the year as well as the quantity of rainfall is likely to contribute to the occurrence of roof leaks, especially for buildings that using a flat roof. If there is a leak in a flat roof, an effective method to detect the exact location of the leak is necessary so that repairs can be carried out effectively.

### 1.3. Condition-based maintenance

#### 1.3.1. Infrared thermography

Infrared thermography used to detect the infrared energy generated by an object. The temperature difference between the normal and the condition with a defect, it will give an indication that the object has a problem. Tsang [25] and Li et al. [14] defined infrared thermography as a method to measure the emissions of infrared energy or radiation from objects and display them in the form of visual heat image, which is also as a mean to determine the operating condition of plant machinery and system. Jadin and Taib [12] highlighted that infrared thermography is the science of obtaining and analysing thermal information from non-contact thermal imaging devices. Through these devices, infrared energy is detected and converted into electronic signals from which a thermal image is produced and displayed on a video monitor to perform temperature calculations. Infrared thermography however, used mostly to detect malfunction on the mechanical and electrical equipment. Applications of infrared camera to detecting faulty in building components usually carried out for damp proof layer, damaged timber caused by termites or exposed clogged pipes. However, this application requires a significant difference in surface temperature of an object for the infrared thermography to detect any anomalies.

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