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# The Research of Infrared Thermal Image Diagnostic Model for Building External Wall Tiles

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## Abstract

This study focuses on a deterioration diagnostic standard and inspection time for external wall tiles. The study was carried out using a tap tone test, followed by fast Fourier transform and pattern recognition to analyse the tapping results. Based on the test results, the study recommends that for frequencies between 200 and 800 Hz on the spectrogram, it can be deduced that a cavity is present in the tiles. The study was carried out using infrared thermal imaging record to deterioration and normal tile position. This study observed temperature changes per hour, it is obvious temperature difference with deterioration tiles and normal tiles between 09: 00-11: 00 (East), 10:00-14:00 (West), 10:00-12:00 (South) and 11:00-13:00 (North), the study was calculated that the average temperature difference of 1.0 degrees. This study suggests that the best experimental inspection time is 09: 00-14:00. Exclude the impact of external factors, if the temperature difference more than 1.0 degrees, it can be deduced that a cavity is present in the tiles, and this can be used as basis for determining tile deterioration.

**Keywords**: external wall tiles, infrared thermal image inspection, tap tone inspection, temperature difference, inspection period

## 1. Introduction

In Taiwan, there has experienced frequent safety incidents involving the external walls of buildings recent years. The most common incidents include falling tiles, falling advertising signage and falling exposed pipelines, all seriously impacting the surrounding environment and public safety. On March 14, 2015, a tile falling incident in Taipei City, Taiwan, resulted in a fatality. According to the Taipei City Government Statistics, there were 1188 buildings listed for control as important cases with spalling wall tiles. The government of Kaohsiung City, Taiwan investigated the 6492 apartment buildings with six or more floors in the city. There were 859 buildings with tiles spalling. Kaohsiung City government listed 367 buildings as important cases for control. According to research data (Chang, 2008), construction in Taiwan peaked in the years 1981 and 1994. According to this research, Taiwanese buildings experience significant deterioration after 30 years. Safety check requirements for Taiwanese buildings should thus peak in 2011 and 2024. Integrating news relating to fatalities in tile-falling incidents in Taiwan, this research sees an immediate need for a complete diagnostic mechanism and preventive method for the further occurrences of such public safety incidents.

To effectively drive external wall replacement safety checks and studies on evaluation systems, the industry requires relevant empirical results and evaluation criteria. This study aims to employ data collection and empirical research to provide a basis of reference and an evaluation method for use in external wall tile diagnosis.

## 2. Method

### *2.1. Tap Tone Method*

This study used sounding diagnosis to complement the visual diagnosis method. The tap tone diagnostic method is the most convenient, economical and widely used evaluation method for inspecting surface defects. Tile inspection is normally combined with other inspection methods (such as the visual inspection method) as a basis for inspection of the condition of wall tile deterioration.

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The theory behind the tap tone diagnostic method is associated with determinations made through sound frequency. Besides pitch, sound also has intensity and tone. Generally speaking, pitch, intensity (loudness) and timbre are the three main elements of sound. The pitch of a sound is determined by its frequency of vibration. A higher frequency of vibration indicates a higher pitch, and a lower frequency of vibration indicates a lower pitch. The intensity of sound is determined by the vibration magnitude (amplitude) of the sound wave. Higher amplitudes equate to more powerful sound waves, and thus louder sounds. Observing the different sounds generated from tapping on normal and deteriorated tiles with a tap tone diagnosis stick, this study uses a Fast Fourier Transform to determine a spectrogram. Frequency (Hz, x-coordinate) and amplitude (V, y-coordinate) are used to form the basis for determining the degree of tile deterioration. Spectrograms from the tap tone diagnosis are shown in Fig. 3 and Fig. 4. The spectrogram's peak and trough for normal tiles show stable frequency (Fig. 1), while deteriorated tiles show apparent instability (Fig. 2).

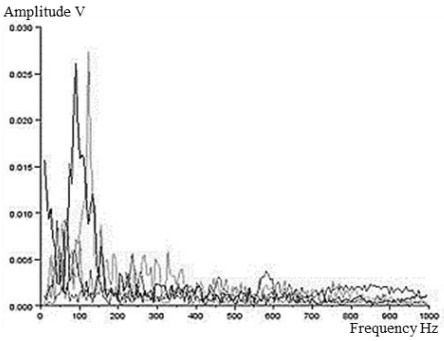



Fig. 1 Transformed spectrum for a tap tone diagnosis on normal tile

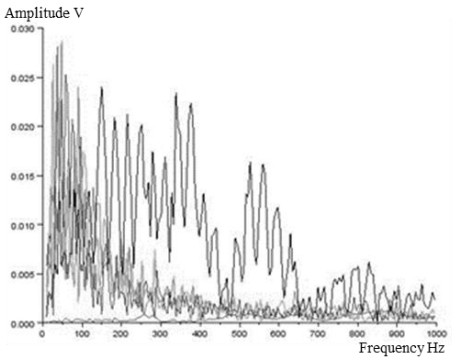



Fig. 2 Transformed spectrum for a tap tone diagnosis on deteriorated tiles

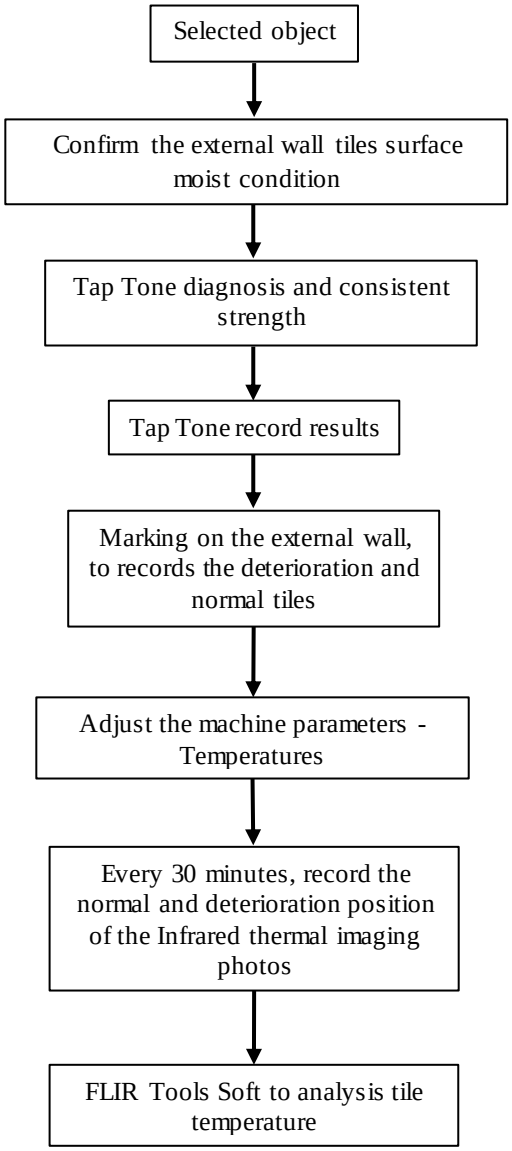



Fig. 3 Test procedure

### *2.2. Infrared Thermal Image Method*

This study uses the infrared thermal imaging to detect building external wall tiles. Infrared thermal imaging method is use natural sunlight, which allows the building wall tile temperature changes. In general, if there is no concrete position defect (bulging phenomenon), infrared thermal imaging displays a consistent surface color. Since the defective portion and the normal portion of different thermal conductivity, this study used infrared thermal imaging device to measurements the temperature difference to determine peeling.

In this study, every 30 minutes to record the external wall tiles temperature of the building, from 09:00 to 17:00, then through the analysis of temperature-time curve to discuss the best measurement time. When detecting the position of internal defects, the temperature deterioration of the position will be higher than other normal area in the day heating period (08:00-11:00), on the contrary, when the cooling time in the day (16:00-19:00), the degradation position will lower temperature than the normal position. And then, this study used tap tone diagnostic method to confirm the deterioration of the range.

## 3. Results and Discussion

### *3.1. Tap Tone Diagnosis Results*

The study carried out tap tone diagnosis on 2 buildings. There are 63 areas of deterioration out of 126 tap tone diagnostic tests. The study deems the first peak of the spectrogram as noise, the beginning of the second wave as the start point of deterioration sound, and its end point as the end point of the deterioration sound. The spectrogram is then segmented by lattice points. Further statistical analysis of the 126 deteriorated areas shows that the average start point of deteriorated tiles is 239Hz, while that for the end point is 761Hz. The deterioration extent is indicated by the shaded portion.

The study suggests that upon tap tone diagnosis, if the Fast Fourier Transform graph shows a frequency from 200 to 800 Hz, it can be speculated that there is a cavity in the tiles. If tap tone diagnosis is required, it is suggested to tap at least 5 spots on the facade to increase overall detection accuracy. The study tentatively recommends that if the tile deterioration ratio exceeds 50%, immediate overall facade renovation of the building should be carried out. If the tile deterioration ratio is less than 50%, then safety measures to prevent surrounding objects from falling should be immediately imposed.

This study investigated 2 building cases in the National Taiwan University. This study used lattice segmentation method for analyzing 126 tiles deterioration image spectrums. It is found that the deterioration of the tiles starts at frequency average about 240Hz and ends at about 760Hz. Deterioration hatched range shown in table 1 and table 2.

Table 1 Case A of tap tone diagnosis results

Case A

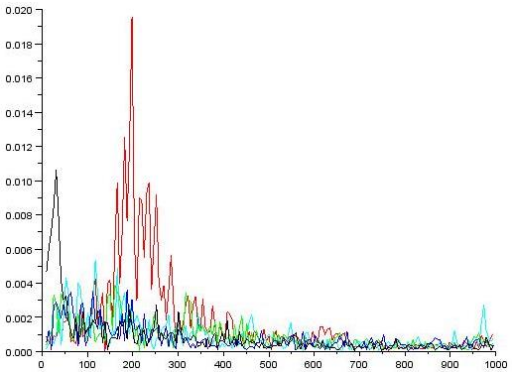
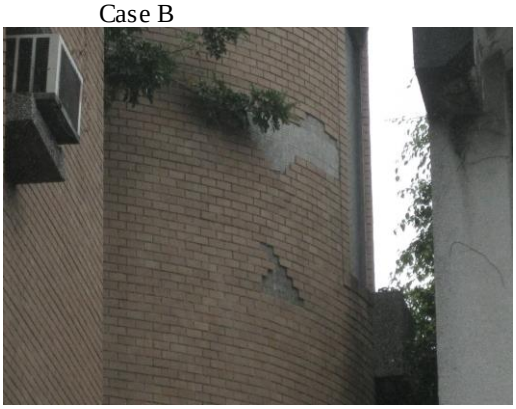
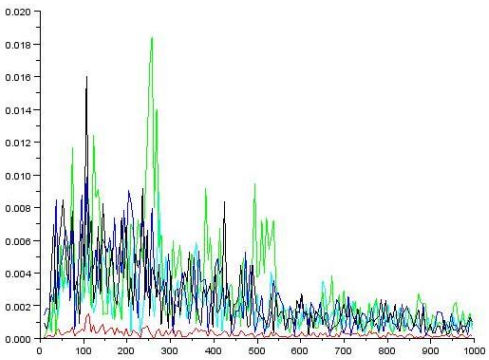



Table 2 Case B of tap tone diagnosis results

Case B





The study consolidates results and recommendations of visual inspection and taps tone diagnosis, and proposes a diagnostic criteria and standard operating procedures for external wall tile deterioration diagnosis of Taiwan buildings.

### *3.2. Infrared Thermal Image Diagnosis Results*

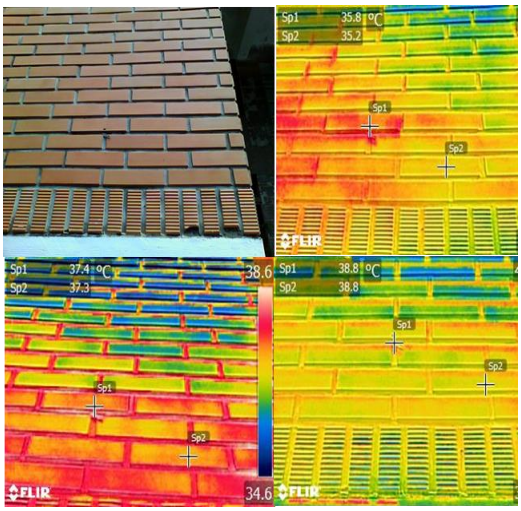



Fig. 4 Case A external wall tiles infrared images (SP1: deterioration, SP2: normal)

According to statistics, the study found that the east tiles maximum temperature is 2.0 degrees, occurred at 9: 00-10: 00. The west tiles maximum temperature is 1.3 degrees, occurred at 12: 00-13: 00. The south tiles maximum temperature is 1.3 degrees also, occurs at 11: 00-12: 00. The north tiles maximum temperature is 1.2 degrees, occurred at 12: 00-13: 00. In this study, the statistics of the external wall temperature, an average temperature difference of 1 degree results. This study suggests that the threshold can be used as observation

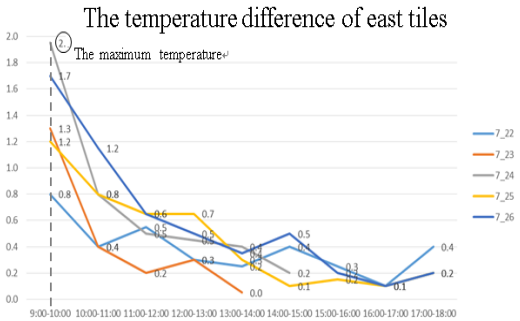



Fig. 5 Case A temperature difference of east external wall tiles

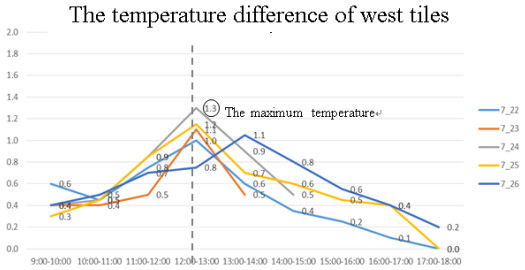



Fig. 6 Case A temperature difference of west external wall tiles

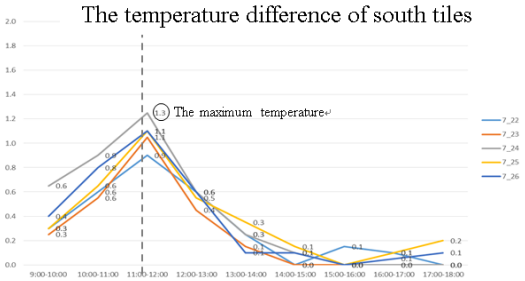



Fig. 7 Case A temperature difference of south external wall tiles

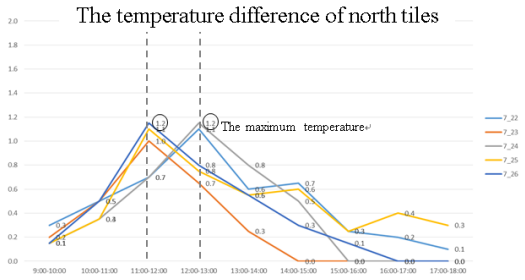



Fig. 8 Case A temperature difference of north external wall tiles

This study analyzed the average of daily temperature difference, the temperature difference if more than one degree, and in the best time of observation of this study suggests, it can be speculated that there is deterioration of tile production. Aggregated data are shown in Table 3.

Table 3 The investigation time and threshold of external wall tiles

| | East | West | South | North |
|---|---|---|---|---|
| Maximum temperature difference | 2.0 | 1.3 | 1.3 | 1.2 |
| Average temperature difference | 1 | 0.9 | 1.1 | 0.9 |
| Recommendation inspection time | 09-11 | 12-14 | 10-12 | 11-13 |

## 4. Conclusions

Since the construction boom in the 1970s in Taiwan, many building external wall have suffered natural deterioration, and many incidents of external wall tiles falling have occurred, with some even resulting in fatalities. As the number of such cases has increased, a complete external wall tile diagnostic system is required. This study proposes public safety visual diagnostic models for external wall tiles of buildings, including Tap Tone and Infrared Thermal Image diagnostic concepts, diagnostic method and diagnostic evaluation reference datum. It also offers a Infrared Thermal Images method for external wall tiles, as well as suggesting the adoption of tap tone diagnosis on tiles that potentially have significant impact on public safety. It also verifies the developed evaluation model, and proposes countermeasures and recommendations for deterioration conditions.

Based on the test results, the study recommends that for frequencies between 200 and 800 Hz on the spectrogram, it can be deduced that a cavity is present in the tiles, and this can be used as basis for determining tile deterioration.

The study was carried out using infrared thermal imaging record to deterioration and normal tile position. This study observed temperature changes per 30 mins, it is obvious temperature difference with deterioration tiles and normal tiles between 09: 00-11: 00 (East), 10:00-14:00 (West), 10:00-12:00 (South) and 11:00-13:00 (North), the study was calculated that the average temperature difference of 1.0 degrees. This study suggests that the best experimental inspection time is 09: 00-14:00. Exclude the impact of external factors, if the temperature difference more than 1.0 degrees, it can be deduced that a cavity is present in the tiles, and this can be used as basis for determining tile deterioration.

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## References

[1] L. W. Chiang, S. J. Guo, C. Y. Chang, and T. P. Lo, "The development of a diagnostic model for the deterioration of external wall tiles of aged buildings in Taiwan," Journal of Asian Architecture and Building Engineering, vol. 15, no.1, pp. 111-118, January 2016.

[2] L. W. Chiang, S. J. Guo, and C. Y. Chang, "The model of visual inspection for building external wall deterioration tiles," Journal of Architecture, vol. 87, pp. 49-66, 2014. (In Chinese)

[3] E. D. Km, "Service life prediction for buildings exposed to severe weather," Journal of Asian Architecture and Building Engineering, vol. 10, no.1, pp. 211-215, 2011.

[4] F. Tong, S. K. Tso, and X. M. Xua, "Tile-wall bonding integrity inspection based on time-domain features of impact acoustics," Journal of Sensors and Actuators A 132, pp. 557-566, 2006.

[5] U. Taketo, K. Kato, and S. Hirono, Non-destructive of the concrete structure, Tokyo: Morikita publishing Co., Ltd, 2000.