The relationships between the extent of mould problems and physical building characteristics in high-rise apartment buildings

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SUMMARY

This paper studies the extent of mould problems in a high-rise apartment complex with six buildings located in suburban of Seoul, Korea. The complex is composed of 466 households with different stories in buildings. The apartment buildings have occupants’ complaints due to mould growth on interior surfaces right after the completion. The research team investigated the sizes of the mould infested areas in each household unit and analyzed them to find any possible relationships between mould extent and physical building characteristics, such as floors of the units, building orientation, number of exposed facades to the outside environment and so on. Although the plan, building materials, construction methods are the same in each apartment household, the difference of mould extent was found with building characteristics. One of the main findings is that the house units on the top floor have larger mould infested areas than the ones on lower stories.

INTRODUCTION

In many countries, microbial growth in indoor spaces has been identified as a main threat to deteriorate the level of Indoor Air Quality (IAQ). Earlier research works have shown that indoor mould growth is likely to occur when a combination of relatively high humidity and temperature on building material surfaces constitutes favorable conditions for mould germination [1]. However, in many cases, mould occurrence involves local, situational, and sometimes idiosyncratic aspects of a building during its operation [2]. Thus, in real situations, it is hard to find the exact causes and appropriate remediation actions, once mould problems are found on building surfaces.

In existing buildings, many studies have been devoted to collect data on the number of mould spores in indoor air using various air sampling methods. However, interpretation of the air sampling results is difficult and dramatically different depending on sampling methods. In the field study by Burge [3], the results of air sampling was not able to indicate fungal contamination in the building, even when visible mould growth appeared in the ventilation system. Miller [4] has concluded that air sampling can be a very useful tool for determining the extent of mould damage of a building only when the exercise of good judgment is provided. The other method is a visual inspection which is to investigate the size of the mould infested areas in existing buildings by experts. Most current guidelines for mould remediation depend on this method and focus on cleaning the affected areas. Although a visual inspection cannot detect hidden mould problems, many mould remediation guidelines have been published and used widely by various agencies and associations. [5, 6, 7, 8].
Despite decades’ research on mould problems in buildings, it has not been studied that the relationships between various physical building characteristics and the extent of mould growth in apartment buildings. Thus, this study focuses on the extent of mould problems in existing buildings using a visual inspection method. The objective of this study is to find any possible relationships between mould infested areas and building characteristics, such as floors of households, building orientation, number of exposed facades to the outside environment and so on. One high-rise apartment complex is selected for this study.

**METHODS**

The selected apartment complex is located in a suburban area of Seoul, Korea, which has hot summer and severe winter. The complex is composed of six high-rise apartment buildings with different number of stories (10 to 24th floors) depending on the lines. The total households are 466 in this complex. 211 units are facing southwest and 255 units are facing southeast. Figure 1 shows the site plan of the selected apartment complex. The structure of the buildings is concrete. Most walls in living areas of the units were finished with wallpaper on the concrete walls except balconies where paint was applied on the concrete walls. The complex has 3 different floor plans in terms of floor area (80, 100, and 160 m²). Figure 2 gives a typical floor plan of the largest unit with 4 bedrooms, 2 bathrooms, and 4 balconies. Smaller units are composed of 3 bedrooms, 1 bathroom, and 3 balconies.

The construction of the complex was finished in 2000. However, the occupants have reported mould infestations inside the buildings after moving in. In August of 2004 our research team has visited the complex and collected information on the severity of mould infestations in all 446 units. The mould infested areas and the location of the mould problems were investigated in each room in the units. Basic building characteristics were also recorded including floors, the face of the units, number of exposed walls to outside, and so on. In this paper the sizes of mould infested areas are analyzed with each building characteristic to find any possible relationships.

![Figure 1. The site plan of the selected apartment complex with six buildings.](image-url)
RESULTS

From the visual inspection of all 466 units in the apartment complex, 240 units (about 51.5%) are found with mould infested areas. The largest infested area is found in the unit located on the top floor (24th floor) of the building #5 with 10.84 ɝ. The distributions of the mould areas have been studied for each building as well. Here we introduce two building cases (building #2 and #4) that are the biggest buildings in this complex.

Figure 3 shows the distribution of the extent of mould infested areas in building #2. In the figure the areas are grouped in 6 categories according to the mould infested areas from 0 (no mould growth) to 10 ɝ. In this particular building all units on the top floor and the bottom
floor have mould problems (except one unit on the first floor). The units in the center of the building have much less mould infested areas than the units in the perimeter of the building.

Figure 4 shows the distribution of the mould infested areas in building #4. In this particular building the units on the top floor shows larger mould infested areas than other units. However a few units in the middle floors have severe mould infested areas as well. The units on the right side of the building seem to have larger mould area than others. But, the difference between the average mould infested areas in the units facing southeast (1.022 ɝ) and southwest (1.104 ɝ) is not significant in the analysis of all 466 units in the complex.

The relationships between the floors of the units and the size of the mould infested areas are investigated in the selected apartment complex. Since the lines in the apartment buildings have different top floors, we analyzed mould infested areas in the units according to lines with the same highest top stories. Figure 5 presents the average mould infested areas in the units in the lines with top floor of 24. The average infested area in the units on the top floor is 3.738 ɝ, which is 3 times greater than the average value of 1.016 ɝ from all 466 units. The units on the 7th floor have the smallest mould infested area of 0.131 ɝ. In this case the mould infested area in the first floor has a larger area than the ones in the middle floors. Thus the units on the bottom floor and the top floor show larger mould infested areas than the ones on middle floors. Similar trend is found in other units in the lines with different top stories, i.e., top story of 10, 15, 19, and 22.
Figure 5. Distribution of mould infested areas in the units that are located in the lines with the top story of 24.

Table 1 Mould infested areas in the units located in the bottom floor and the top floor $[\text{m}^2]$.

<table>
<thead>
<tr>
<th></th>
<th>BR1</th>
<th>BR2</th>
<th>BR3</th>
<th>Bal.1</th>
<th>Bal.2</th>
<th>Bal.3</th>
<th>Bal.4</th>
<th>Bath1</th>
<th>Bath2</th>
<th>LR</th>
<th>Total &amp; Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bottom floor units (24)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td>2.250</td>
<td>6.020</td>
<td>0.200</td>
<td>8.510</td>
<td>4.840</td>
<td>3.720</td>
<td>0.000</td>
<td>0.039</td>
<td>1.016</td>
<td>0.000</td>
<td>26.595</td>
</tr>
<tr>
<td>Avg.</td>
<td>0.094</td>
<td>0.251</td>
<td>0.008</td>
<td>0.355</td>
<td>0.202</td>
<td>0.155</td>
<td>0.000</td>
<td>0.002</td>
<td>0.042</td>
<td>0.000</td>
<td>1.108</td>
</tr>
<tr>
<td><strong>Top floor units (24)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td>2.620</td>
<td>0.000</td>
<td>0.000</td>
<td>19.000</td>
<td>28.630</td>
<td>10.870</td>
<td>0.000</td>
<td>0.685</td>
<td>0.843</td>
<td>0.000</td>
<td>62.648</td>
</tr>
<tr>
<td>Avg.</td>
<td>0.109</td>
<td>0.000</td>
<td>0.000</td>
<td>0.792</td>
<td>1.193</td>
<td>0.453</td>
<td>0.000</td>
<td>0.029</td>
<td>0.035</td>
<td>0.000</td>
<td>2.610</td>
</tr>
</tbody>
</table>


Table 1 summarizes the mould infested areas with average values in each room of the units located in the bottom floor and the top floor in all six buildings. The average area for the bottom floor is 1.108 $[\text{m}^2]$ that is similar to the average value in all units (1.016 $[\text{m}^2]$). However, top floor units shows over 2 times higher value of 2.610 $[\text{m}^2]$ than the ones in all units. Balconies in the top floor unit have much larger mould infested areas compared to the ones on bottom floor (See Bal.1~Bal.3). Thus, balconies on the top floors are the most vulnerable space for mould growth in these specific apartment buildings.
Figure 6. Percentage of mould infested areas in rooms.

Apartment units are typically composed of bedrooms, bathroom(s), living and kitchen areas, and enclosed balconies in a high-rise apartment in Korea. In this particular apartment complex, the balconies are enclosed with concrete walls and windows which are exposed to the environment. Thus, the balconies can be considered an interior space without heating or cooling systems. Figure 6 shows the percentage of mould infested areas in each room. Although the walls in balconies are finished with paint on concrete, balcony accounts for 90.4% of the total infected areas. Bedrooms and bathrooms are account for 7.1% and 2.3% of total area, respectively. It is thought that the severe mould growth on balcony walls is due to the condensation and heat bridge effects on the line joints and window sills. Further research will be conducted to find the main causes of mould growth in the balcony space.

Figure 7. Average mould infested areas in the units with 2 or 3 exposed facades.

Figure 7 shows the average mould infested areas in the units with 2 or 3 exposed facades. This apartment complex has 136 units with 2 exposed facades and 282 units with 3 exposed facades. In this analysis the units located on the top and bottom floors are not included to exclude additional effect of the roofs and ground. The units with 3 exposed facades have an average mould infested area of 1.05 (🟦) which is larger than an average area of 0.85 (⬜) for
the units with 2 exposed facades. In the analysis of individual room, balcony 1 accounts for most increase of mould infested area in the units with 3 exposed facades as shown in the figure.

DISCUSSION

This study investigated the mould infested areas in all 466 households in a high-rise apartment complex. In the study of house units located in the first floor and the top floor revealed that the units on the top floor have over 2 times larger average mould infested areas compared to the average value of all units. Especially, the balconies on the top floors are the most vulnerable space for mould growth.

In the analysis of mould infested areas and the number of exposed facades, the units with 3 exposed facades showed larger mould infested areas than the one in the units with 2 exposed facades. Particularly, balconies in the units with 3 exposed facades need special attention to reduce the extent of mold growth. In conclusion, the balconies in the units located on the top floor with 3 façades should be carefully examined to avoid mould favorable environmental conditions.

In this particular apartment buildings balcony spaces showed most severe mould growth in terms of the sizes of the mould infested area, which accounted for 90.4% of the total infested area. It is interesting that mould can grow well on the painted concrete walls in the balconies. According to Baughman[9] and Nielsen [10], concrete is one of the least favorable building materials for mould to grow due to not sufficient amount of nutrients. However, if favorable temperature and humidity are provided for enough time, mould spores on the concrete walls can germinate and grow as reported in the case study by Moon [2]. Thus, it is possible that concrete walls in balcony may have mould infestations due to condensation, heat bridge effects, or not enough thermal insulation. Designers and architectural engineers should pay special attentions to the environmental conditions in balconies.

At this stage of the research no investigations have been conducted to find the main causes of mould growth in the balcony spaces. This will be done as a future research by looking at the details of the buildings and measuring the environmental conditions including surface temperature and relative humidity.

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REFERENCES


