

Environmental Deterioration Factors in Metal Claddings and GFRC Panels Implemented on Facades: An Assessment through Two Cases in Istanbul

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Abstract. *Decrease in performance of building facades, components, and materials before their service life is an unexpected situation. Therefore, detecting the probable causes of these anomalies plays a crucial role in maintenance planning. This study aims to determine the environmental deterioration factors which affect the performance of buildings, especially building façades, through two case buildings situated in the same university campus in Istanbul. The methodological framework of the study is based on visual observations and literature review. Through observations on a different period of time, anomalies have been detected and photographed. In the first case, it has been focused on metal claddings on building façade. In the second case, it has been focused on GFRC panels which have the majority of the North façade. Within the help of literature and observations, two cases have been compared to each other in terms of their deterioration factors and interpreted through graphs. In the first case, occurred deteriorations have been detected such as uniform dirt, corrosion, joint degradation, mechanical impacts, and delamination. In the second case, deteriorations have been observed such as biological staining, uniform dirt, moisture rising, and design failures.*

Keywords: *Environmental Deterioration Factors, Building Façade Failures, Metal Claddings, Glass Fibre Reinforced Concrete Façade.*

1 Introduction

Performance of a building deteriorates in time depending on environmental effects, usage, maintenance, detail design and type of materials which are used in building envelope. Therefore, defining the probable causes of deteriorations has high importance to propose appropriate solutions.

Environmental agents are divided into natural (wind, rain, freeze and throw, and solar radiation), and chemical and biological problems, issued by air pollution (Norvaišienė *et al.*, 2003). The data reported in this paper investigates environmental agents which can affect performance of façade.

A research called “Climatic and Air Pollution Effects on Building Facades” has a deep literature review on degradation mechanisms that affect the durability of building materials (Norvaišienė *et al.*, 2003). A study called “Evaluation of Damage of Building Facades in Brasilia” aims to evaluate age and climatic agents through quantitative research. Visual inspections and facade mapping were used as a method and some degradation agents such as grout and sealing failures and efflorescence are examined over the exposure to solar radiation

(Bauer *et al.*, 2014). By now, many kinds of research have been done on deterioration factors and durability of materials. Defining these factors/mechanisms correctly is essential in order to propose appropriate solutions in design, construction, and maintenance process.

2 Environmental Factors

Mechanisms are generally examined in three categories: physical, chemical, and biological (Dickinson *et al.*, 1999). *Physical mechanisms* are related to the presence of water. Freezing and thawing processes with the temperature and moisture differences may cause stress and crack on the material (Norvaisiene *et al.*, 2003). *Chemical mechanisms* involve some chemical compounds that can react with the building surface. Particulate matters in the air generally comprise dust, smoke and suspended particles. Dust particles being large and heavy, settle quickly and will not affect large areas. Smoke and suspended particles being smaller and lighter remain in the atmosphere for a longer time and affect larger areas (Chew *et al.*, 2003). Sulfur and nitrate have acidic concentrations, and they cause acid rain, which is a threat to human health and also building envelope (Norvaisiene *et al.*, 2003). Besides, corrosion of materials can occur due to chemical interaction with the environment. If corrosion of materials does not prevent in time, it may cause even structural deteriorations.

In *biological mechanisms*, wind changing the direction of rain drops to façade and this is “one of the most important moisture sources” that effects durability of façade material. These destructive effects can be “frost damage, discoloring, biological and chemical degradations” and also structural cracking (Blocken *et al.*, 2013). Also rain water is one of the reasons of stains on façade. It can wash the dirt through the façade and also is a major factor that causes biological grow on it. “Sunlight plays an important role in affecting the formation of stains on a facade. The intensity and duration of sunlight that a surface receives affect the limit of runoff flow, the type of biological stains and the pattern of staining” (Chew *et al.*, 2003).

3 Case Studies

In this part, two case buildings where are located in Istanbul are selected in order to understand environmental deterioration factors. In this context, there is an approach from macro to micro scale, which begins with defining the surrounding of the buildings and continues with the building facade components.

3.1 Local Environment

Both of the case buildings are located in Maslak, where is one of the main business districts of İstanbul. The altitude is 120 meters, and distance from the sea is approximately 3 km. In the first case, the northern facade of the building is facing Buyukdere Street, which usually has heavy traffic flow. Also, there is viaduct which is passing near the case building and facing the northern facade of the first case building again. The other side of Buyukdere is a high-density urbanized area which has many commercial and residential complexes.

In the second case building, traffic direction is in North and East face. There is also a parking lot in the West side. The site plans of the case buildings are given in Figure 1:

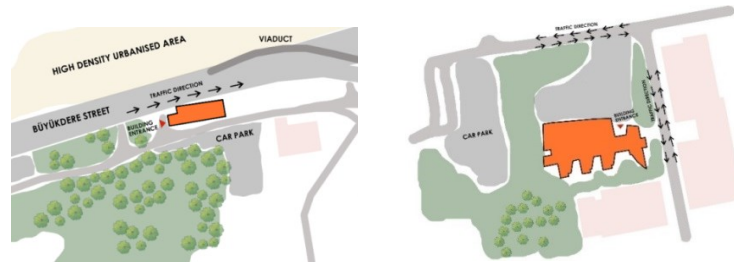


Figure 1. Site plans of the first and second case buildings.

3.2 Micro Environment

Istanbul where the case buildings are located has mild-humid climatic characteristics. According to the official statistics, the highest temperature is in July (41.5°C), and the lowest average temperature is in February (-16.1°C). The average number of rainy days is highest in January (17.3) and the lowest in July (4.3). Maximum daily precipitation is 128.9 mm (Turkish State Meteorological Service Official Web Sites, n.d.).

The dominant wind direction in the district is North – North East. Accordingly, it is assumed that the northern façade of the building is exposed to more wind and rain. Figure 2 shows the location of the case buildings in macro scale. Distance from the sea is approximately 3 km that can be an adequate distance to happen convection of salt.

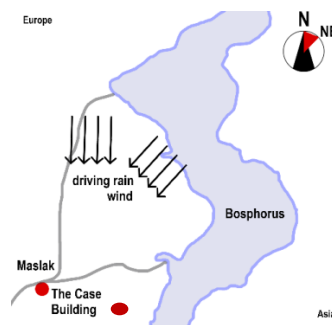


Figure 2. Location of the case buildings.

The recent measurements performed by Ministry of Environment and Urbanization show that PM_{10} and NO_2 values are comparatively increasing in the rush hours as a probable consequence of Buyukdere Street (SİM Project n.d.). Also, a report which has been prepared in 2018 by the Netherlands Enterprise Agency shows the existing situation within the context of air pollution in İstanbul. According to the European Directive, the number of permitted exceedances per year is 18. Figure 3 shows that NO_2 limit is exceeded more than 18 times in 6 stations in 2017 and Maslak district has the third highest exceedance level (Standards-Air Quality-Environment-European Commission, n.d.). As understood, the selected buildings are located in a highly urbanized area and air pollution in the district is quite a lot. Therefore, the selection of appropriate material for the building envelope is a critical issue.

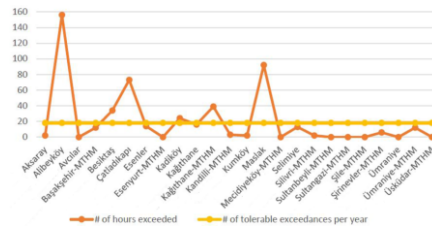


Figure 3. Frequency of hours the NO₂ limit was exceeded in 2017.

3.3 Façade Components

The first case building façade mainly has 4 mm thickness white colored *aluminum composite panel* (1), *siliconized glass system with an aluminum frame* (2), *structural steel columns* (3), *natural stone cladding* (4), *silver-gray colored aluminum mesh cladding* (5) and *white colored aluminum dynamic vertical and fixed horizontal shading elements* (6) (Figure 4).

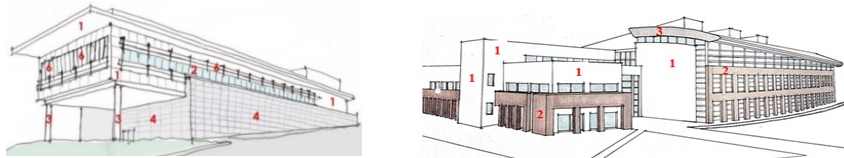


Figure 4. Façade components of the first and second case buildings.

Materials that have been used on façade for the second case building are (most to least); *glass fibre reinforced concrete (GFRC)* (1), *clinker based facade panels* (2), *aluminum* (3). It has been focused on metal claddings in the first case and GFRC panels in the second case since they have the most deterioration in comparison with other materials on the façade.

4 Preparation for Field Observation

The methodological framework of the study is based on visual observations and literature review. Firstly, façade deterioration factors have been defined in detail through literature. For the field observation, two datasheets have been prepared. The first datasheet contains the general information such as primary use of the building and construction process. The second one involves atmospheric exposures such as wind, rain, sun that affects the building façades, climate in the observation days and deterioration types. After collecting data, anomalies on building façade have been detected and shown in façade mapping (Figure 5).

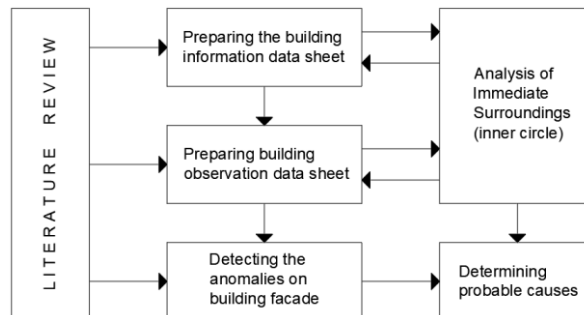


Figure 5. The methodology of the study.

5 Analysis and Discussions

For the first case building, four observations were made. The first one was made on 27th April 2015, in a cloudy day, 18°C at 09:30 am. The second one was on 25th September 2018, rainy day, 19°C. The third one was 9th October 2018, cloudy day, 16°C at 12:00 am and the fourth observation was on 4th December 2018, after rain, 10°C at 05:30 pm.

For the second case, the first observation was in 22th October 2018, 15:35 in partly cloudy weather. The second one was in 10th November 2018, 17:09 in a completely sunny weather. The last observation was made after two heavy rainy days in 19th November 2018, 14:22.

5.1 Case Study 1

According to the observations, anomalies detected on the selected building facades are examined. Deteriorations are classified into five categories. These are; uniform dirt (A), corrosion (B), joints degradation (C), mechanical impact (D), and delamination (E). The deteriorations which have been detected are shown in façade mapping (Figure 6).

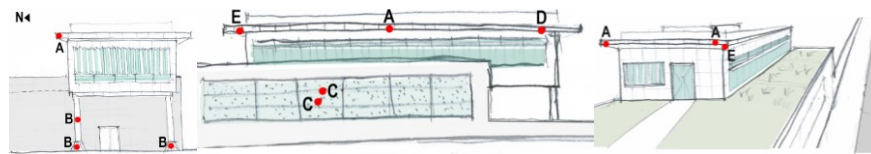


Figure 6. Deteriorations on the West, North, and East façade.

Uniform dirt has been mostly seen on the aluminum composite panels and shading elements (Figure 7). The most dirtiness has been concentrated on the overhangs that have 10-12 meter height from Buyukdere Street. Especially the North and East facade are the dirtiest facades of the building. The reason may be the viaduct which passes above the main road and brings all the pollution onto the façades within the help of dominant wind and driving rain.

Deterioration Type	A	Date	9.10.2018
		Weather data	Cloudy, 16°C
		Affected parts	Aluminum composite panel Overhangs and facades, shadings
		Affected facades	North, South, East, West
		Probable causes	Atmospheric pollution

Figure 7. Deterioration type A, 'uniform dirt'.

The observations which have been made in 25th September and 4th December 2018 show that two structural columns on the West façade of the building have been deteriorated by corrosion effect (Figure 8). The waterhole has been observed below the feet of the column after the rain. Accordingly, degradation on the feet is thought to be due to the wrong slope angle. Deterioration on the column head may be related with the storm water runoff.


Deterioration Type	B	Date	25.09.2018, 04.12.2018
		Weather data	Rainy, 19°C, after rain 10°C
		Affected parts	Structural steel column column head, body, and feet
		Affected facades	West
		Probable causes	Atmospheric pollution wrong slope (ground level) stormwater runoff

Figure 8. Deterioration type B, ‘corrosion’.

According to the observation on 9th October 2018, joints degradations have been detected on the North façade, which has covered with aluminum mesh cladding (Figure 9). This deterioration may be the consequence of stiff breeze coming from the North and North-East direction. Also, wrong detail design may cause to happen in this situation.


Deterioration Type	C	Date	9.10.2018
		Weather data	Cloudy, 16°C
		Affected parts	Aluminum mesh cladding
		Affected facades	North
		Probable causes	Atmospheric effects (wind, rain) wrong detail design (WDD)

Figure 9. Deterioration type C, ‘joints degradation’.

The observation on 9th October 2018 makes think about a mechanical impact on the North façade overhang, which is covered with aluminum composite panels (Figure 10).


Deterioration Type	D	Date	9.10.2018
		Weather data	Cloudy, 16°C
		Affected parts	Aluminum composite panels Overhang
		Affected facades	North
		Probable causes	

Figure 10. Deterioration type D, ‘mechanical impact’.

According to the observation on 4th December 2018, delamination is seen on the North and East overhangs (Figure 11). Probable cause is thought to be the storm water runoff with the wind which is coming from the dominant direction. It may have penetrated from the joints and caused the delamination of layers on the composite panels.


Deterioration Type	E	Date	4.12.2018
		Weather data	After the rain, 10°C
		Affected parts	Aluminum composite panels Overhang
		Affected facades	North, East
		Probable causes	Stormwater runoff

Figure 11. Deterioration type E, ‘delamination’.

5.2 Case Study 2

According to the observations, anomalies detected on the selected building facades are examined. Deteriorations are classified into three categories. These are; biological staining (A), moisture rising (B), and joints degradation (C). The deteriorations which have been detected are shown in façade mapping (Figure 12).

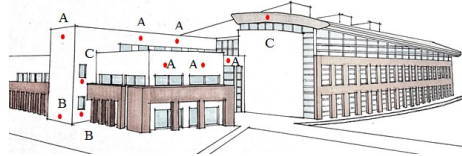


Figure 12. Façade mapping of the second case building.

According to observations, the building is exposures to the prevailing wind, which changes the direction of raindrops. As the most deteriorated part of the façade is the N/E (Figure 13), lack of sunlight slows down the procedure of drying after it had been wetted, and results as biological staining (due to algae, bacteria, and fungi).

Deterioration Type	A	Date	22.10.2018, 19.11.2018
		Weather data	Partly cloudy, Rainy
		Affected parts	GFRC panels
		Affected facades	North, East
		Probable causes	lack of sunlight after rains

Figure 13. Deterioration type A, 'biological staining'.

N/E façade is directly in contact with ground and grasses. Because of continuous dampness, external wall of this part of façade is stained. As a result, mould growth appeared and there was discoloration to the wall (Figure 14).

Deterioration Type	B	Date	10.11.2018, 19.11.2018
		Weather data	Sunny, Rainy
		Affected parts	GFRC panels, Clinker panels
		Affected facades	North, East
		Probable causes	Continuous dampness, WDD

Figure 14. Deterioration type B, 'moisture rising'.

Panel joints and sealants on a façade provide for drainage of run-off on the facade. Joints affect runoff can locally rinse away deposited dirt stains at areas where a file of vertical joints is broken and where joints are slanted (Figure 15).

Deterioration Type	C	Date	10.11.2018, 19.11.2018
		Weather data	Sunny, Rainy
		Affected parts	GFRC panels, Aluminum
		Affected facades	North, East
		Probable causes	Atmospheric effects (wind, rain) wrong detail design

Figure 15. Deterioration type C, 'Joints degradation'.

7 Conclusion

In this study, field observation has been done for two case buildings, and probable causes on façade deteriorations have been examined with the help of literature.

The district of both cases has air pollution due to high urbanization and heavy traffic intensity. Especially in the first case, some deteriorations have been observed after only three years of usage on the North, East, and West façades which are close to the main road and the viaduct. According to the literature, aluminum composite panels should be cleaned at least once in a year. Besides, stormwater runoff should be controlled to prevent the corrosion of steel materials. To delay or prevent necessary significant renovations for the future, maintenance planning should be done and implemented periodically.

This paper helps to understand the expected behavior of GFRC panels and metal claddings for Istanbul province and similar climatic conditions. More data and laboratory analysis is required for this method to produce more reliable façade degradation mapping.

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