Research Article

The Evaluation of the Effect of Mass Housing Facades on Comfort Conditions: The Example of Ataköy



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Abstract: *Houses are spaces in which occupants spend long hours and expect to have the comfort conditions (thermal, visual, acoustic). A large portion of increasing energy consumption as a result of technological developments and industrialization is for heating and cooling residential buildings and residential buildings are increasingly located more in areas that are exposed to high external noise levels which all increase the level of importance for facades to provide thermal and acoustic comfort conditions. Ataköy region is an example of a residential area that shows the effects of developments in our country with changes in architectural approaches and construction technologies since its establishment. The objective of this study is to assess facade performances of public housing buildings which were built with different facade characteristics in different periods in Ataköy for thermal and acoustic comfort and energy consumption. To do this, the efficiency of the facade systems of the residential buildings which were built with different materials and facade systems and similar block layout in the 1950s and 1980s in a neighbourhood with high traffic noise in Ataköy was assessed. Heating and cooling energy loads and thermal performance evaluation of selected buildings were calculated by Design Builder simulation program and noise reduction values of facades were calculated by the KS program. The comparative results of the changes in thermal and acoustic comfort and energy consumption in the buildings constructed by using brick and concrete facade panels were assessed using charts.*

Keywords: *Building envelope, noise control, energy efficiency.*

Toplu Konut Cephelerinin Konfor Koşullarına Etkisinin Ataköy Örneği Üzerinden Değerlendirilmesi

Öz: *Konutlar, kullanıcıların içinde uzun zaman geçirdikleri ve konfor koşularının sağlanmasını (termal, görsel, işitsel) bekledikleri alanlardır. Yaşanan teknolojik gelişmeler ve sanayileşme ile artan enerji tüketim miktarlarının büyük bir kısmının konutlardaki ısıtma ve soğutma faaliyetlerinde kullanılması ve hızlı kentleşme ile yüksek dış gürültü düzeylerinden etkilenen konut yerleşim alanlarının bulunması cephelerin özellikle ısısal ve işitsel konfor koşullarını sağlamaktaki önemini arttırmaktadır. Ataköy bölgesi kuruluşundan itibaren mimari yaklaşımları ve yapım teknolojilerindeki değişimler ile ülkemizde yaşanan gelişmelerin etkilerini gösteren bir yerleşim bölgesi örneğidir. Bu çalışmanın amacı Ataköy'de farklı dönemlerde yapılmış olan farklı cephe özelliklerine sahip toplu konutlarda cephe performanslarının ısısal, işitsel konfor ve enerji harcamaları açısından değerlendirilmesidir. Bu nedenle, Ataköy'de yoğun trafik gürültüsünün olduğu bir bölgede bulunan ve benzer blok yerleşimine sahip 1950'li ve 1980'li yıllarda farklı malzeme ve cephe sistemleri ile yapılmış konut yapılarında cephe sistemlerinin etkinlikleri değerlendirilmiştir. Seçilen bloklara ait ısıtma ve soğutma enerji gereksinimleri ve ısıl konfor değerlendirmesi Design Builder simülasyon programı ile gürültü azaltım değerleri ise KS programı ile hesaplanmıştır. Cephelerinde tuğla ve beton cephe panelleri kullanılan bloklarda ısıl ve işitsel konfor ile enerji harcamalarındaki değişimin karşılaştırmalı sonuçları grafikler yardımıyla incelenmiştir.*

Anahtar Kelimeler: *Bina Kabuğu, gürültü kontrolü, enerji etkinliği.*

1. INTRODUCTION

Migration from rural areas to cities has been increasing with increasing population, increased machine use in agriculture and industrialization which can be seen easily in population statistics: increase in urban population was 20.1% between 1940-1950 whereas this shot up to 80.2% between 1950-60 [1]. Housing problems caused by increasing internal migration and fast urbanization have been attempted to be solved with different housing policies in different periods. One of these solutions is mass housing projects which refer to a high number of residential building production in a shorter time and with less investment [2]. Ensuring indoor thermal and acoustic comfort conditions in residential buildings where occupants spend extended period of times is even more important in mass housing which includes many residential buildings and affects a high number of occupants.

In traditional construction systems used in residential buildings, construction process is done on the construction site increasing the need for labour and prolonging the construction period. Therefore, also with the effect of developments in the construction industry, new actions have been taken to accelerate construction of mass housing and modular ready mixed concrete wall elements and prefabricated panel systems which allow fast production and convenience in implementation have started to be preferred. The use of precast elements in buildings such as in public housing where elements are used repetitively has increased construction speed [3]. Additionally, with the lessons learned during the oil crisis in the 1970s, efficiency in energy consumption has been popular to reduce foreign dependency [4]. Works that aim energy efficiency have also affected facade design as a result of their architectural design. Changes in building systems, facade and design decisions have been observed in buildings depending on the characteristics and developments during the period of construction.

Environmental and economic problems as a result of increased fossil fuel consumption, limited energy resources and negative effects of increasing environmental noises on people underlines the importance of architectural design decisions. Priorities in a building design include design variables such as building location, building form, position of a building relative to others, orientation of units and properties of building elements around units which affect energy consumption and noise reduction. Correct decisions about these variables will enable to provide comfort conditions in a residential building for many years with minimum energy consumption. Building façades are among the most effective design variables for creating indoor thermal and acoustic comfort conditions and determining energy loads required for controlling outdoor environment conditions. This study assesses the efficiency of facades for energy consumed to achieve thermal and acoustic comfort conditions in the mass housing blocks built using different construction systems in Ataköy district of Istanbul.

2. THE IMPORTANCE OF FACADES IN ENSURING ENERGY EFFICIENCY AND THERMAL, ACOUSTIC COMFORT CONDITIONS

Fast population growth, advances in technologies, changing consumption habits with urbanization and industrialization increase energy demand worldwide. Limited use of resources to meet increasing energy demands and environmental problems caused by the use of such resources increase the importance of studies on the concept of energy efficiency which means the most efficient use of energy resources from production to consumption. Regarding the distribution of energy consumption among industries, residential buildings have a major share in the total energy consumption. In Turkey, residential buildings are responsible for 40% of total energy consumption and majority of the energy is consumed by heating and cooling systems to achieve thermal comfort conditions [5]. The extent that the thermal comfort conditions in residential building are met with minimum energy consumption is directly proportional to how well passive systems in those buildings are designed.

Another important environmental problem as a result of increased urban population and intense urbanization today is noise. The World Health Organization (WHO) considers noise as the second most important type of environmental pollution after air pollution [6]. Control of noise which is described as disturbing, unsolicited sound and ensuring indoor acoustic comfort conditions is getting more important with increased number of sources of noise and the change in expectations about indoor comfort conditions. Indoor noise levels higher than acceptable limits have a negative effect on human health and performance. Residential areas are exposed increasingly more to environmental noises as a result of fast urbanization and industrialization which requires taking actions against environmental noises for the well-being and health of building occupants.

Building envelope design, one of the passive design decisions in buildings has an impact on both thermal and acoustic comfort conditions. Passive design decisions about the building envelope taken in the beginning play an important role in ensuring indoor thermal comfort conditions and acoustic comfort conditions with minimum energy consumption. With controlled heat transfer in the building envelope, use of man-made heating systems and related heating and cooling energy loads are reduced [7]. Additionally, with selection of the optimum building facade that has sufficient insulation during the design stage, thermal comfort can be achieved and potential comfort problems due to technical or financial matters can be prevented [8].

Therefore the building façade is the determinant factor for;

- energy consumption caused by heat losses and gains and
- noise reduction value for outdoor environment noise

is the most important design variable and has the priority in design decisions about the building envelope.

3. STUDY METHOD

Thermal and acoustic comfort conditions in the existing mass housing buildings included in this study and change in the heating, cooling and overall energy loads to achieve thermal comfort conditions depending on facade performances were comparatively assessed. For thermal comfort, operative temperature and solar radiation gains of the units and energy loads consumed to achieve thermal comfort conditions in units were calculated and for acoustic comfort, noise reduction values of building façades of the units were calculated. Design Builder simulation program was used for thermal performance evaluations and energy consumption calculations of the units with different facade properties and KS (Kalksandstein Schallschutzrechner) simulation program was used to calculate noise reduction values of facades. Design Builder program used in this study is a simulation program which uses Energy Plus simulation motor to determine thermal and visual comfort conditions and calculate energy loads. The Design Builder program runs as an interface of the Design Builder Energy Plus software program developed by the US Department of Energy and calculates hourly, daily, monthly, and annual data [9]. KS (Kalksandstein Schallschutzrechner) (V 7.03) software program used in the study is an acoustic calculation program in accordance with the ISO 12354 standards. It is used to calculate noise transfer loss of the building envelope and inner wall elements [10].

3.1. Determining building variables

Residential buildings included in this study are in Ataköy region of Bakirkoy district in Istanbul with temperate humid climate conditions in the 2. Degree Day Region of Turkey [11]. In this study residential buildings in Phase 1 which were built in the 1950s with the facade systems used in that period and in Phase 5 which were built in the 1980s with the facade systems used in that period were assessed.

Residential buildings included in the study are on a level land and on Bakırköy seaside road. These buildings are not in the shadow of other buildings. Buildings included in the study were chosen from the buildings which are closest to the seaside road and have similar orientation and outdoor noise levels. The satellite photo of the layout of the residential buildings included in the study was shown in Figure 1.

Figure 1. Layout plan of Ataköy neighbourhood.

Buildings in the phases 1 and 5 differ in building form. Therefore, thermal and acoustic performance assessments of the buildings were done in living rooms and bedrooms on which the building facade has a direct effect. Plans of residential buildings and the positions of the living rooms and bedrooms to be assessed and building facades are shown in Figure 2.

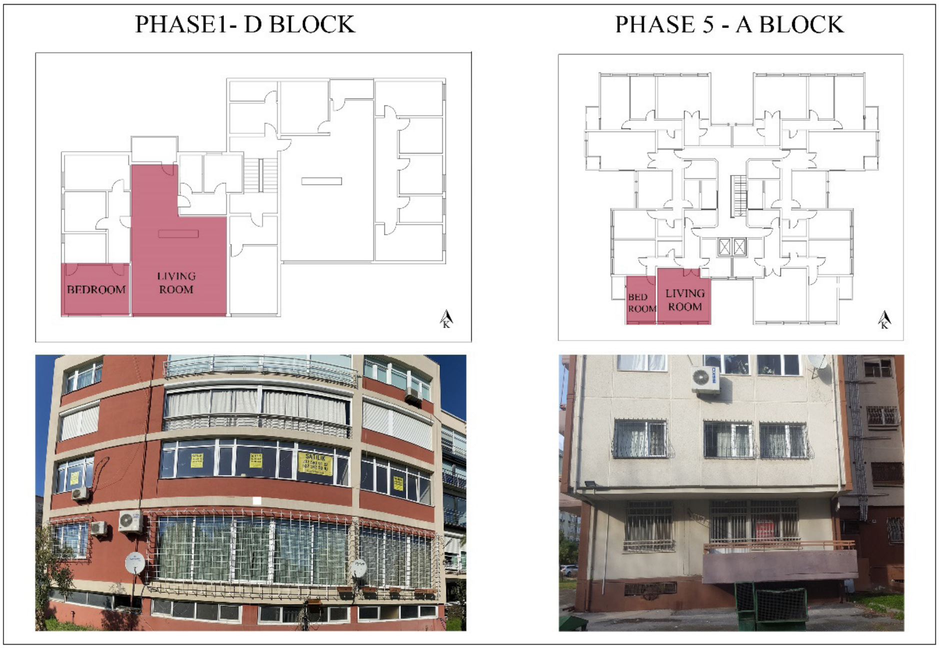


Figure 2. Building plans and views

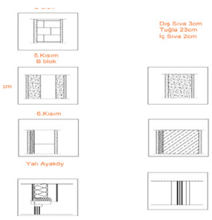
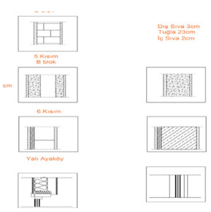
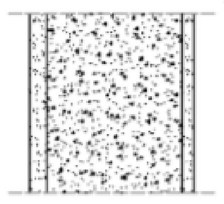
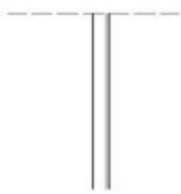
Double-glazed windows with PVC frame were used in the buildings. Total heat transfer coefficient (Up) of the windows is 1.96 W/ m² and weighted sound reduction index is Rw: 37(-2,-4). Orientation and transparency ratios of living rooms and bedrooms are shown in Chart 1.

Chart 1. Orientation and transparency ratios of living rooms and bedrooms.

	BLOCK	SOUTH	WEST
LIVING ROOM	Phase 1 BLOCK D	62%	-
	Phase 5 BLOCK A	25%	-
BED ROOM	Phase 1 BLOCK D	31%	-
	Phase 5 BLOCK A	23%	18%

Block D in phase 1 has brick facades and Block A in phase 5 has precast concrete cladding on facades. Building envelope properties of the buildings included in the study are shown in Chart 2.

Chart 2. Residential building envelope details

Block	Layering	Material	Width (m)	Density (kg/m^3)	Heat Trans mission λ (W/m-K)	Heat Transfer Coef.(U) (W/m^{2}K)
PHASE 1, BLOCK D		Internal Plaster Brick Wall External Plaster	0.02 0.23 0.03	1000 1700 800	0.4 0.84 0.18	1.588
PHASE 5 BLOCK A		Internal Plaster Concrete Block Air gap Concrete Block External Plaster	0.02 0.12 0.15 0.08 0.03	1000 1800 - 1800 800	0.4 1.35 - 1.35 0.18	1.517
		Internal Plaster Concrete Block External Plaster	0.02 0.20 0.03	1000 1800 800	0,4 1,35 0,18	2,087
PHASE 1-5 BLOCK D-A		Clear Glass Air Gap Clear Glass	0.003 0.013 0.003	-	-	1,96

3.2. Calculation variables

Thermal performances of building façades were comparatively evaluated for the energy consumed to achieve operative temperature change, solar radiation gains and thermal comfort conditions. Operative temperature and solar radiation gains in units were calculated for January 21st which represents the coldest day and for July 21st which represents the hottest day of the year. In order to compare energy loads of the buildings which have different building forms, heating, cooling and overall energy load values per square meter in living rooms and bedrooms were calculated.

For all climate data about the external environment, data with epw. Extension (Energy Plus Weather) created for Istanbul in the Design Builder simulation program was used. For outdoor noise levels, noise maps developed by the Environmental Protection Department of Istanbul Metropolitan Municipality were used and the level of noise that the building façades were exposed was set at 70dBA [12].

Calculations for the residential buildings included in the study were done for living rooms and bedrooms which have the priority for achieving comfort conditions. Indoor comfort temperature was set at 20°C for the heating period and at 26°C for the cooling period in the residential buildings that are used on 24/7 basis. The limit temperature to activate the heating system was set at 18°C and the limit temperature to activate the cooling system was set at 28°C. For indoor noise and facade noise reduction values, the limit values stipulated in the Regulation on Protection of Buildings from Noise (2017) were used [13]. These values are 44 dBA for living rooms and 41 dBA for bedrooms which are D acoustic performance class values which should be met for the existing buildings. A system running on natural gas with hot water circulation was used as the heating system and electrical systems were used as the cooling system in the buildings included in the study.

4. RESULT

In this study building envelope details which change depending on the construction year of the buildings were determined and thermal and acoustic performance;

- operative temperature change and solar radiation gains,
- energy consumed to ensure thermal comfort conditions and
- noise reduction values

of the building facades were comparatively assessed. Calculation results for living rooms are shown in Figure 3 and calculation results for bedrooms are shown in Figure 4.

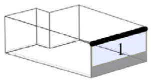
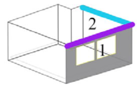
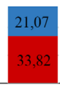
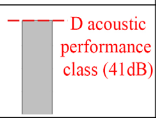
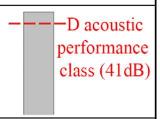
Blocks / LIVING ROOM	PHASE 1 D BLOCK		PHASE 5 A BLOCK	
				
Transparency Ratio	SOUTH (%62)		SOUTH(%25)	
Facade Material	Brick(23cm)		Concrete Block (35cm) Concrete Block (20cm)	
Total Heat Transfer Coefficient (W/m²K)	Wall: U_w: 1,588		Wall: U_{w1}: 1,517 U_{w2}: 2,087	
	Window: U_w: 1,960		Window: U_w: 1,960	
Average operative Temperature(°C)	*21January*	*21July*	*21January*	*21July*
	7,98	32,56	6,75	28,53
Max-Min Value Difference (°C)	0,41	2,04	0,28	1
Overall Solar Radiation(kWh)	3,97	21,69	1,02	5,55
Annual Overall Energy Loads Graphic Heating Loads Cooling Loads				
kWh/m²	54,89		73,98	
Rw+Ctr (dB)	Rw_D: 52,3 Rw_P: 33		Rw_{D1}: 63,8 Rw_{D2}: 51 Rw_P: 33	
Rw+Ctr (dB) composite	Rw: 36		Rw: 42,3	
Dntw+Ctr				
(dB)	41		42	
Acoustic Performance Class	**(D)**		**(D)**	

Figure 3. Living room calculations

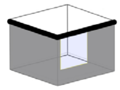
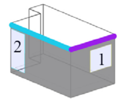
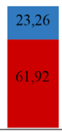
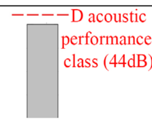
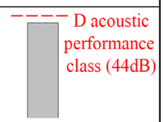
Blocks / BED ROOM	PHASE 1 D BLOCK		PHASE 5 A BLOCK	
				
Transparency Ratio	SOUTH (%31)		S.O.1: SOUTH (%25) S.O.2: WEST (%18)	
Facade Material	Brick(23cm)		Concrete Block (35cm) Concrete Block (20cm)	
Total Heat Transfer Coefficient (W/m²K)	Wall: U_w: 1,588		Wall: U_{w1}: 1,517 U_{w2}: 2,087	
	Window: U_w: 1,960		Window: U_w: 1,960	
Average operative Temperature(°C)	*21January*	*21July*	*21January*	*21July*
	7,47	32,15	6,46	28,58
Max-Min Value Difference (°C)	0,25	1,61	0,22	0,92
Overall Solar Radiation(kWh)	1,35	7,37	0,51	2,77
Annual Overall Energy Loads Graphic Heating Loads Cooling Loads				
kWh/m²	85,18		104,02	
Rw+Ctr (dB)	Rw_D: 52,3 Rw_P: 33		Rw_{D1}: 63,8 Rw_{D2}: 51 Rw_P: 33	
Rw+Ctr (dB) composite	Rw: 40.5		Rw: 42.5	
Dntw+Ctr				
(dB)	40,2		40,8	
Acoustic Performance Class	**(E)**		**(E)**	

Figure 4 . Bedroom calculations

When the changes in the operative temperature and solar radiation gain values of living rooms of the buildings on January 21 and July 21 and annual changes in heating, cooling and overall energy load per square meter were calculated;

- Daily average operative temperature and overall solar radiation gain values in living rooms on January 21 which represents the heating period and on July 21 which represents the cooling period were higher in Block D in Phase 1 than in Block A in Phase 5,

- The difference between minimum and maximum values of daily average operative temperatures in living rooms on January 21 and July 21 was higher in Block D in Phase 1 than Block A in Phase 5 due to increased building transparency ratio,

- While heating loads were lower in Block D in Phase 1 which was built in 1950s than Block A in Phase 5 which was built in 1980s due to solar radiation gain, cooling loads were higher,

• None of the buildings meet the minimum requirements for total heat transfer coefficient recommended by the standard TS-825 Thermal insulation requirements for buildings as a result of the buildings' ages. Under these circumstances, annual overall energy load was higher in Block A in Phase 5 than Block D in Phase 1 and there was a 35% increase in overall energy load.

When opaque and composite component and facade noise reduction values of living rooms in the buildings were calculated;

• Noise reduction value of the opaque component was higher in Block A in Phase 5 due to the building's facade properties,

• The noise reduction value of the composite component which includes both opaque and transparent components was higher in Block A in Phase 5 with lower transparency ratio, where transparent component properties were the same but noise reduction value of the opaque component was higher,

• The noise reduction value (Dnt,w) that varies depending on outdoor noise on building facades and indoor noise sensitivity degree was high in Block A in Phase 5 due to noise reduction value of the opaque component and transparent component ratio,

• Although they were built before the Regulation on Protection of Buildings from Noise became effective, the buildings were found to meet the minimum acoustic performance class requirements stipulated in the regulation based on the choice of material, layering details and transparency component ratio in Block D in the Phase 1 and Block A in the Phase 5.

When the changes in the operative temperature and solar radiation gain values of bedrooms of the buildings on January 21 and July 21 and annual changes in heating, cooling and overall energy load per square meter were calculated;

• Daily average operative temperature and overall solar radiation gain values in bedrooms on January 21 which represents the heating period and July 21 which represents the cooling period were higher in Block D in Phase 1 than in Block A in Phase 5,

• The difference between minimum and maximum values of daily average operative temperatures in living rooms on January 21 and July 21 was higher in Block D in Phase 1 than Block A in Phase 5 due to increased building transparency ratio,

• While heating loads were lower in Block D in Phase 1 which was built in 1950s than Block A in Phase 5 which was built in 1980s due to solar radiation gain, cooling loads were higher,

• None of the buildings meet the minimum requirements for total heat transfer coefficient recommended by the standard TS-825 Thermal insulation requirements for buildings as a result of the buildings' ages. Under these circumstances, annual overall energy load was higher in Block A in Phase 5 than Block D in Phase 1 and there was a 22% increase in overall energy load consumptions.

When the opaque and composite component and facade noise reduction values of bedrooms in the buildings were calculated;

• Noise reduction value of the opaque component was higher in Block A in Phase 5 as a result of mass and material properties of the building façades,

• The noise reduction value of the composite envelope which includes both opaque and transparent components was higher in Block A in Phase 5 with lower transparency ratio, where transparent component properties were the same but noise reduction value of the opaque component was higher,

• The noise reduction value (Dnt,w) that varies depending on outdoor noise on building facades and indoor noise sensitivity degrees was higher in Block A in Phase 5 due to the opaque component and transparent component ratio

• These buildings which were built before the Regulation on Protection of Buildings from Noise became effective, failed to meet the minimum acoustic performance class requirements stipulated in the regulation based on the choice of material, layering details and transparency component ratio in Block D in the Phase 1 and Block A in the Phase 5.

5. CONCLUSION

Developments throughout history have an influence also on architectural developments and based on the developments unique to each period, search for new implementation techniques, systems and materials have continued. The structural element that is affected the most by changes and developments during architectural development process is the façade [14]. It is very important to achieve thermal, visual and acoustic comfort conditions with minimum energy consumption to protect occupant health and ensure energy preservation. One of the most important functions of the building envelope which connects outdoor environment to indoors is to control physical factors such as climate, light, sound and ensure that comfort conditions needed by occupants are met with minimum energy consumption. Decisions on facades in mass housing projects which cover a high number of residential buildings will affect occupants for many years. In this study, the effects of facade decisions in buildings which were built before the standard "TS-825 Thermal insulation requirements for buildings" and "Regulation on Protection of Buildings from Noise" became effective and with different facade systems in line with the architectural developments of the years they were built were assessed. The study results are summarized below.

Regarding thermal performance and energy consumptions;

• Buildings did not meet the limit values stipulated by the thermal insulation regulation and

the transparency ratios in Block D in Phase 1 and Block A in Phase 5 which were built before 1980 had an effect on solar radiation gains and therefore on overall energy loads,

• As the transparent component ratio on the building facade increases, heating loads decrease and cooling loads increase in the living room oriented to the south. In the bedroom volumes, although there are transparent components on both sides (south and west), it was observed that heating loads increased and cooling loads decreased in the block with lower transparency on the south side.

• Based on the simulation results, depending on the changes in facade properties and transparency ratios, 99% increase in heating loads and 69% decrease in cooling loads and 34% decrease in overall energy loads in Block D in Phase 1 compared to Block A in Phase 5 were observed. %54 increase in heating loads and 65% decrease in cooling loads and %22 decrease in overall energy loads were found in bedrooms.

• Change in the facade system and transparent component ratio between blocks that have a total heat transfer coefficients which do not meet the requirements of TS 825 had more effect on cooling loads,

• Regarding operative temperature values; the value which is closest to the comfort temperature value set for January 21 was achieved in Block D in Phase 1 and the value which is closest the comfort temperature value set for July 21 was achieved in Block A in Phase 5. In this case, less energy was consumed for heating systems in Block D in Phase 1 and for cooling systems in Block A in Phase 5 in which values closest to the required comfort temperature were achieved.

According to the acoustic performance assessments;

• Noise reduction value of the opaque component was higher in Block A in Phase 5 which had precast concrete cladding, due to mass and material properties of the building facades,

• Regarding the composite component that consist of opaque and transparent components;

since transparent component properties were the same, it changed depending on the noise reduction value of the opaque component and ratio of the transparent component which has a lower insulation performance,

• Noise reduction values of building facades of living rooms in Block D in Phase 1 and Block A in Phase 5 which are located close to main roads and in a district with a high noise level were higher while noise control measures should be improved in bedrooms which are more sensitive to noise,

• Despite high outdoor noise, the buildings that were built before the Regulation on Protection of Buildings from Noise became effective in 2017 met the requirements of minimum acoustic performance class for living rooms in existing buildings however facade properties were insufficient for bedrooms which have a high sensitivity to noise.

This study found that decisions about materials, layering and transparency ratio for the facades of mass housing buildings built with different facade systems in the same district had an impact on thermal and acoustic comfort conditions and energy consumptions. Design decisions in mass housing systems in which many residential buildings are built simultaneously have a more important role than they have for single building constructions. Although residential buildings are built in accordance with the regulations that were effective during their construction, they are expected to meet comfort requirements throughout their lifespan. Fast depletion of energy resources and increasing environmental noise emphasizes the importance of assessment of existing buildings which constitute a majority of the building stock. While mass housing units which will meet comfort conditions with minimum energy and in compliance with the effective laws and regulations in new mass housing projects developed to find solutions to increasing demand for housing are being built, energy consumption and thermal and acoustic comfort conditions in old mass housing buildings which do not meet the requirements of today's regulations should also be put on the agenda.

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