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Two real room fire and the evaluation of its consequences in terms of fire safety

Mustafa Altın [a,*], Muhammed Furkan Kılıçarslan [b]

[a] Konya Technical University, Vocational School of Technical Sciences, Department of Construction, Konya, Turkey
[b] Konya Technical University, Graduate School, Department of Civil Engineering, Konya, Turkey

A R T I C L E I N F O

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Thermal image

A B S T R A C T

In this study, 1/1 scale Fire Experiment Laboratory was built to demonstrate the reality of fire with a real fire. In the prepared building, there are 2 fire test rooms measuring 300 × 350cm and 1 observation room measuring 190 × 620cm. In the fire tests, a living room and a bedroom were furnished by calculating the required fire loads. In the fire load calculation, a fire index value of 1.18 was obtained in the bedroom and a fire index value of 1.86 was obtained in the living room. Instant temperature values were taken for each second in the lower, middle and top zones of the fire rooms. The bedroom reached maximum temperatures around 1200 °C in the top zone, 800 °C in the middle zone and 400 °C in the lower zone. And in the living room, maximum temperatures were measured at around 900 °C in the top zone, 600 °C in the middle zone and 300 °C in the lower zone. Moreover, temperature changes outside the building were also recorded. According to the thermal camera images measured, the external wall temperature of the bedroom is around 25–31 °C at maximum temperature and the external wall temperature of the living room is around 41–46 °C at maximum temperature.

1. Introduction

Accidental fires in residential buildings are risky events that affect human life both directly and indirectly, affecting general public health. Fires are recognized as one of the most significant natural disasters, causing approximately 200,000 deaths annually worldwide. Although fire-related injuries and deaths are common in low- and middle-income countries, this issue is also of concern in high-income countries [1].

In order to prevent material and moral losses due to fires in residential areas, the causes of these fires should be identified [2]. Human error and risky behaviors are the main causes of most fire incidents, while knowledge about the people affected by fire is necessary to find the most effective method to prevent unwanted residential fires [3]. Information such as how a person exposed to a fire behaves and how their experiences are shaped is important. Necessary measures should be taken to prevent recurrence by examining the factors related to the outbreak of fire, human behavior and the consequences of injuries caused by fire.

It can be said that real fire performances are needed to validate the spread model on the software platform and will play an important role in monitoring fire spread [4]. Accurate and reliable prediction of the smoke generation process is critical for building fire protection design [5]. Decision making in residential fires can be difficult to study in an experimental setup. With virtual reality, the behavior and reactions of people in residential fires can be simulated [6]. Buildings need to be designed to provide an acceptable

* Corresponding author. Vocational School of Technical Sciences, Konya Technical University, 42003, Selcuklu, Konya, Turkey.
E-mail addresses: maltin@ktun.edu.tr (M. Altın), muhammedfurkankilicarslan@gmail.com (M.F. Kılıçarslan).

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level of fire, minimizing heat, smoke and safety risks. Observations from realistic fires show that the building floor collapses due to fire [7]. At the same time, the design was created in a real building in terms of both energy saving and fire safety [8]. The need for sustainability is leading to the construction of more airtight buildings, and buildings with better thermal insulation are being produced to improve the energy efficiency of homes, and specific fire hazards also arise in such buildings [9].

The scientific study of the harmful effects of indoor fires on building structures and on the environment is a top issue today. Indoor fires frequently occur all over the world [10]. In recent years, there has been an increasing number of projects related to fire research, primarily focused on understanding fire dynamics through full-scale experiments. However, less is known about real fire events [11]. Fire load is the largest contributor to the rate of heat release, which defines the severity of a fire event in buildings. In order for residential buildings to achieve an adequate fire safety design, it is necessary to have a well-defined fire load [12].

At the different stages of fire development and extinguishing at the fire site, the temperatures of the material burning by physical and chemical processes, the intensity of the flame, the amount of water required to extinguish the fire and the feedback systems are also important [13]. In order to make decisions in all the interventions to be made, it is very important to conduct fire experiments at a real scale and make decisions according to the data obtained and provide data for different software. Fires in different types and facilities around the world pose a serious problem [14–16].

Real-time prediction of building fire development and critical fire events is of great importance for firefighting [17]. Real-time intelligent fire detection and prediction approaches can be detected through cameras based on computerized image processing [18]. Real-time fire protection architectural design systems are being developed for building safety [19]. At the same time, evacuation-path-selection modeling of real-time fire spread in urban areas can be used to study underground complexes, improve fire safety management plans, and assist in the development of intelligent emergency evacuation systems [20]. Studies are being carried out to optimize fire extinguishing time and optimal consumption of fighting agents [13].

Statistics on the number and nature of fires occurring in a country play a major role in planning and implementing the future of fire services at a national level. Knowing the number of fires, their causes and consequences have an important guiding role in designing fire precautions, deploying fire stations, determining the behaviors of the society that need to be raised awareness, and determining the teams and their equipment. These issues are also clarified by regulations and what is required to be done is constantly updated [21]. If it is known where there have been more fires, where and why deaths and injuries have occurred, the solutions to be applied are easy to find. Therefore, it is important to pay great attention to fire statistics. Efforts are being made to evaluate these statistics and to reduce or prevent their consequences. As a result, one of the most important units of the fire departments of developed countries has been organized as a statistical evaluation unit [22].

Istanbul Fire Department Istanbul Province fire statistical data for 2015–2022 is given in Fig. 1. When the statistics are analyzed, it is seen that housing and building fire totals have the largest structural rate, even if they vary by year [23]. In the light of these statistical data, the idea of experimental investigation of residential and building fires was formed.

2. Material and method

2.1. Building properties

For the experimental studies, a Fire Test Laboratory was designed within the Konya Technical University Vocational School of Technical Sciences, Department of Construction and a 1/1 scale building was prepared. The ground floor plan and the finished images of the building are given in Fig. 2. There are 2 rooms measuring 300 × 350 cm and 1 room measuring 190 × 620 cm in the fire test building. The building was constructed in masonry construction technique with 20 cm thick aerated concrete on the walls and 15 cm thick reinforced aerated concrete as a ceiling slab [24].

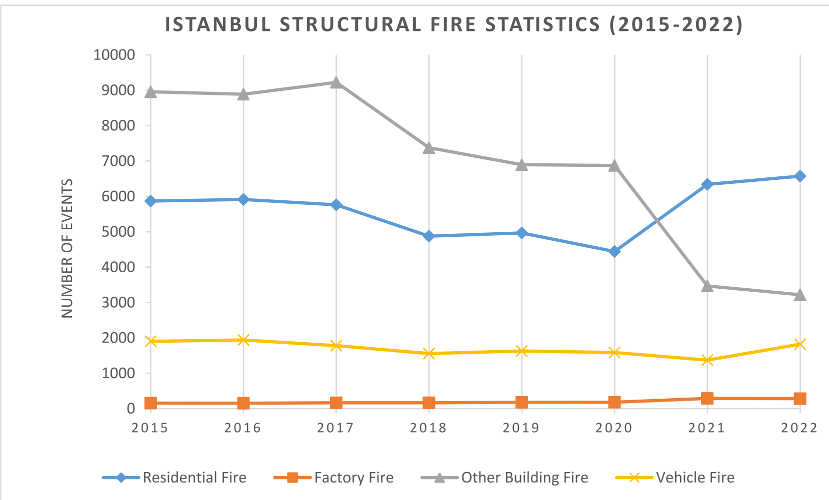


Fig. 1. Istanbul structural fire statistics (2015–2022) (URL-1) [23].

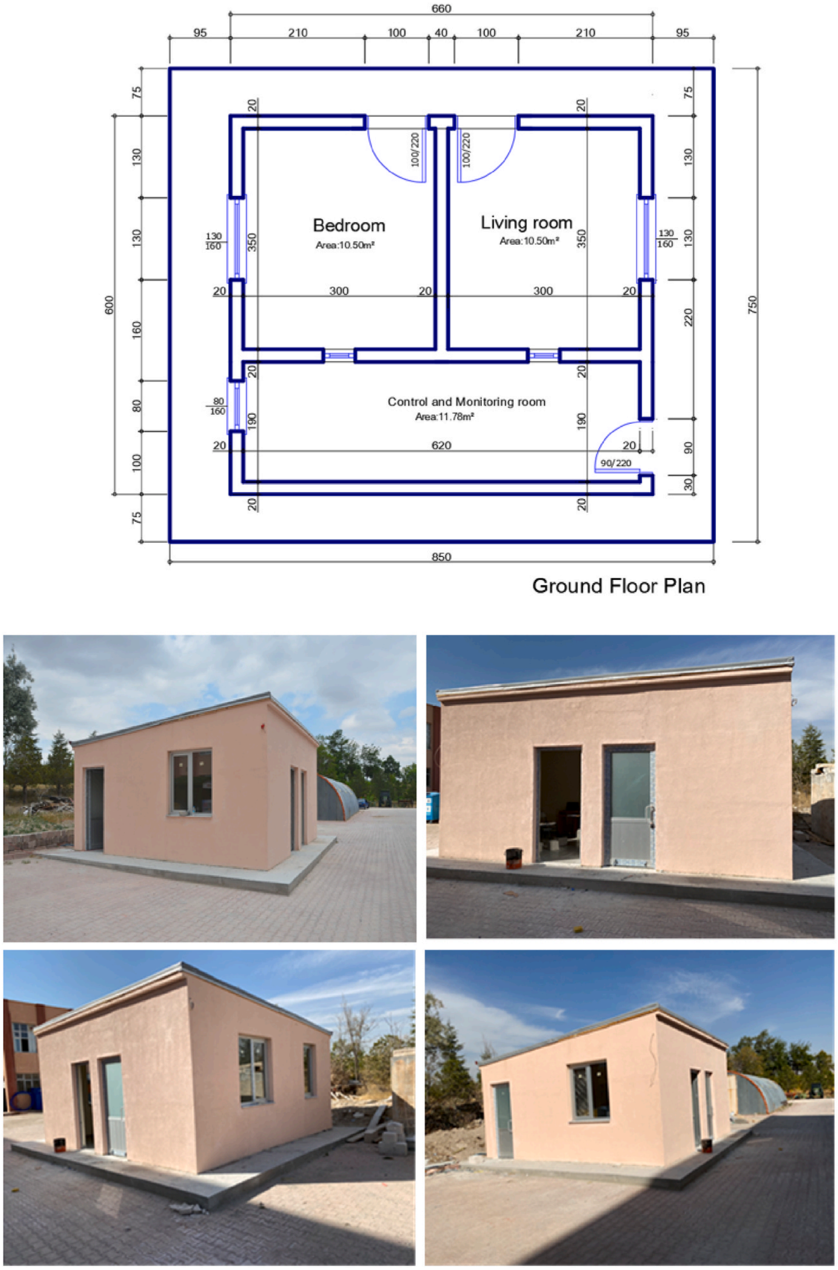


Fig. 2. Ground floor plan and finished images of the building.

2.2. Material properties

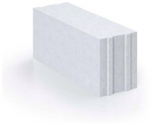
Technical details of the aerated concrete used in the walls, technical details of the reinforced aerated concrete used in the roof and technical details of the aluminum profile doors, windows and rockwool in the building are given in Table 1.

Aerated concrete as wall material and reinforced gas concrete as a roofing material are widely used in both thermal and fire insulation, and rock wool insulation material preferred as an insulation material is a widely used material with known thermophysical properties. Aluminum doors and windows, another material used in the experimental study, are known as a thermophysical features suitable material with high thermal insulation properties that comply with fire regulations and do not cause toxic gas emissions.

After the materials required for the fire experiment (heat measurement devices, software, other necessary equipment for measurement, thermal camera, indoor furniture, roller blinds, observation room, room layout) were completed, the experiments were started. In the experiment, instantaneous temperature recordings from inside and outside the building were made with specially developed software.

With the thermal camera, laser heat, and humidity meter with a camera and digital thermometer used in the experiment, both

Table 1
Technical details of gas concrete, reinforced gas concrete, aluminum profiles and rock wool.

	Technical detail of gas concrete [25].	
	Length	600 mm
	Width	85–400 mm
	Height	200 mm
	Average Compressive Strength (Cube Specimen)	2,5 N/mm^2
	Average Gross Dry Density	400 kg/m^3
	Reaction to Fire	A1
	Coefficient of Water-Vapour Permeability	5/10
	Heat Conductivity Factor	≤0,106 W/m.K
	Technical detail of reinforced gas concrete [26].	
	Yield Strength	500 mPa
	Tensile Strength	550 mPa
	Reaction to Fire	A1
	Coefficient of Water-Vapour Permeability	5/10
	Heat Conductivity Factor	≤0,16 W/m.K
	Technical detail of aluminum door and window [27].	
	Well Depth	45 mm
	Blade Depth	54,5 mm
	Shape Wall Thickness	1,3 mm–1,5 mm
	Maximum Substance	30 mm
	Thermal Barriers	15 mm
	Thermal Insulating Value (Uf)	3,54 W/m^2K
	Technical detail of rock wool [28]	
	Length	1200 mm
	Width	600 mm
	Thickness	50 mm
	Density	110 kg/m^3
	Heat Conductivity Factor	0,034 W/(m.K)
	Reaction to Fire	A1
	Melting Point	≥1000

internal and external temperature measurements and the development processes of the fire were monitored before and after the fire. The digital thermometer used in the experimental study is 1200°c temperature sensitive and has been calibrated by the Turkish Accreditation Agency (TS EN ISO/IEC17025) [29] according to the calibration certificate number H12S392. Technical information and features of the device are given in Table 2. Flir brand T200 model infrared thermography will be used in the experimental studies. The properties of the infrared thermograph are given in Table 3.

During the fire experiments, a camera laser heat and moisture meter with technical specifications given in Table 4 was used.

2.3. *Experiment study plan*

2.3.1. *Temperature experiments*

Temperature experiments were carried out by placing thermocouples on the ceilings inside the room and at the corner points outside the building during the fire. Fig. 3 shows the layout of the fire test building, heat meter and data measurement device.

2.3.2. *Thermal camera*

In this study, Flir brand T200 model infrared thermography, whose technical specifications and images are given in Table 4, was used for thermal images. Instant thermal images were recorded from the beginning of the experiment in the living room and bedroom. The images were opened in the Flir T200 device application and experimental studies were carried out by obtaining the results of the desired point values.

Table 2
Elimko (E-TC01-1K1K09-25-1/4) device technical specifications.

Devices drawing	Technical specifications
	- NiCr-Ni IEC 60584 type thermocouple, - Resistant to a maximum of 1200 °C since the element diameter is 1 mm, - Its pipe is DIN standart 1.4571, - Protective sheath diameter 9 mm, - Thermocouple length 250 mm from the its head

Table 3
Technical specifications of Teledyne FLIR T200.

Product Images	Device	Brand	Version	Features
	Infrared camera	Teledyne FLIR	T200	Measurement range −20 + 350 °C Resolution: 0.08 °C Connection: USB, memory card Weight: 880 gr Internal camera

Table 4
Technical specifications of BOSCH GIS 1000 C Professional [30].

Product Images	Device	Brand	Version	Features
	Infrared Thermometer	Bosch	GIS 1000 °C	Measurement range 40 … +1000 °C Resolution: 0.1 °C Laser class: 2.635 nm Connection: micro USB, Bluetooth Internal camera Internal relative moisture meter

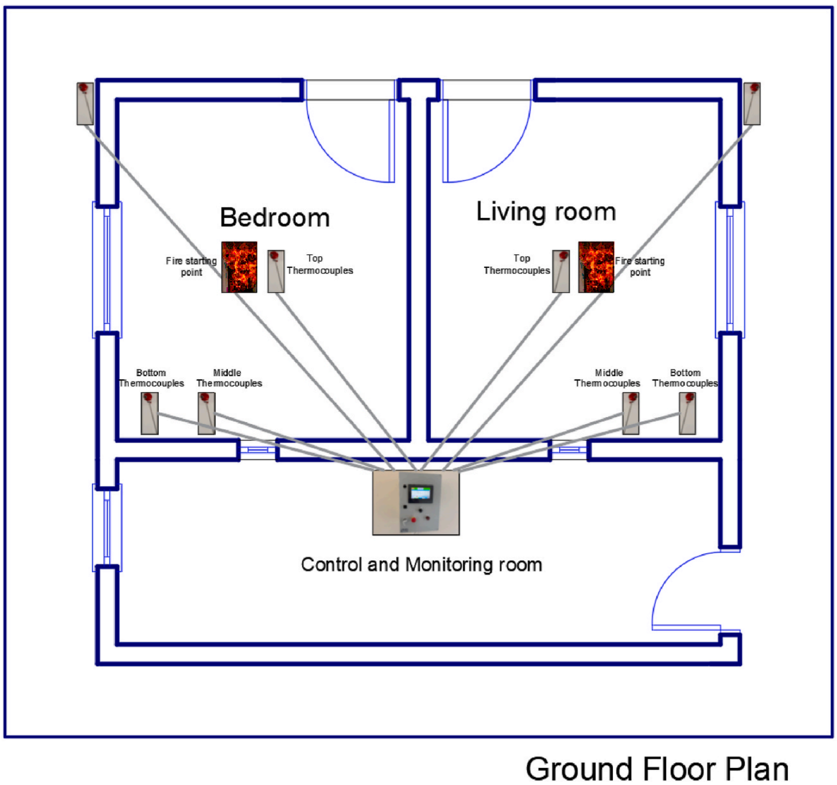


Fig. 3. Fire test building, thermometer, data measurement device plan and fire starting point.

2.4. Construction phases of the fire experiment building

The outer walls of the fire test building are made of 20 cm thick aerated concrete. The experimental building was prepared as 2 experimental rooms and 1 observation and control room. A window was left in the observation and control room to observe both rooms. One of the rooms, whose interior visuals are given in Fig. 4, was designed and furnished as a Living room.

One of the rooms, whose interior visuals are given in Fig. 5, was designed and furnished as a bedroom.

Fig. 4. Living interior images.

3. Results and discussion

3.1. Fire load

Fire load calculations were obtained in units of (mJ/m^2) by dividing the sum of the values found by multiplying the lower heating value of the material by the mass of the combustible material by the total area. The value obtained was converted into a fire index value and the results were interpreted through the evaluation table. Table 5 shows the fire load calculation for the living room and Table 7 shows the fire load calculation for the bedroom [1].

Fire load value in the room designed as a living room according to the data in Table 6.

$$FIRE\ LOAD = \frac{TOTAL(M \times IHV)}{TOTAL\ AREA} \tag{1}$$

Fire load = 1865,13 mJ/m^2 Fire load index = 1865.

Looking at the range of fire load values in the living room from the fire index table given in Table 7, it is seen that the room has a fire hazard and there is even a risk of fire storms that can escalate the fire and turn it into a disaster. Hence, during the experiment, the fire caused serious damage and affected the other experimental room, the bedroom.

Fire load value in the room designed as a bedroom according to the data in Table 8.

$$FIRE\ LOAD = \frac{TOTAL(M \times IHV)}{TOTAL\ AREA} \tag{2}$$

Fire load = = 1183.18 mJ/m^2 Fire load index = 1183.

Looking at the fire load value range in the living room from the fire index table given in Table 8, it is seen that the room has a fire hazard risk. Hence, during the experiment, the fire caused serious damage and the room became unusable. During the experiment, the fire developed and spread to the eaves of the experimental building.

As a result of the fire load calculations, a fire index value of (1.18) was calculated for the bedroom. A fire index value of 1.86 was observed in the living room. These values in the index suggest that there is a danger of fire spread in both rooms and even the possibility of a fire storm due to strong air flow if the fire in the living room reaches large levels.

Knowing the fire load of the rooms in a burning structure is important information for fire safety. Because it shows how destructive fires in different rooms or compartments can be and gives an idea of how likely a fire is to spread from one area to another. Firefighters use this information to identify the most vulnerable or dangerous areas of burning buildings. It is also a matter of consideration when constructing a building. For example, because the concrete does not burn, it does not contribute to the fire load and is therefore often

Fig. 5. Bedroom interior images.

Table 5
Living room fire load calculation.

Flammable Substance Name	Mass of Flammable Material (kg)	Lower Heat Value (IHV)(mj/kg)	M x IHV
Couch	120	28,98	3477,6
Roller blind 1	1,95	15,51	30,2445
Computer desk	29,76	16,42	488,6592
Carpet	10,35	15,51	160,5285
Monitor	11,5	36	414
Bookshelf	60	16,42	985,2
Book	55	19,93	1096,15
Lamp	0,22	18	3,96
Canvas (tuval)	2	19	38
Diagrammatic cardboard chart	1	20	20
Tile	192125	48	9222
Window	41,12	36	1480,32
Door	60,2	36	2167,2
	Total (M × IHV)		19583,8622
	Total Area (m^2)		10,5

Table 6
Fire index table (Living room).

CLASSIFICATION BY FIRE INDEX	
0,00–1,00	There's no danger of fire spread.
1,00–1,50	There is a danger of fire spreading.
1,50–2,50	**There is a danger of area fire and firestorms.**
2,50–3,50	There is a high probability of a firestorm.
3,50>	In case of fire, disaster is inevitable.

Table 7
Bedroom fire load calculation.

Flammable Substance Name	Mass of Combustible Material (kg)	Lower Heat Value (IHV) (mj/kg)	M x IHV
Mattresses + headboard	140	35	4900
Bed	22	33,1	728,2
Wardrobe	70	20,04	1402,8
Carpet	3,6	15,51	55836
Sheets	0,5	16,61	8305
Shoes	5	28	140
Slippers	3	19,65	58,95
Clothes	10	15,51	155,1
Roller blinds	1,95	15,51	30,2445
Lamp	0,22	33,1	7282
Table (calendar)	0,5	14,84	7,42
Diagrammatic cardboard chart	1	13	13
Laminate flooring	77,26814516	16,42	1268,74294
Window	41,12	36	1480,32
Door	60,2	36	2167,2
	Total (M × IHV)		12423,40044
	Total Area (m^2)		10,5

Table 8
Fire index table (Bedroom).

CLASSIFICATION BY FIRE INDEX	
0,00–1,00	There's no danger of fire spread.
1,00–1,50	**There is a danger of fire spreading.**
1,50–2,50	There is a danger of area fire and firestorms.
2,50–3,50	There is a high probability of a firestorm.
3,50>	In case of fire, disaster is inevitable.

used to construct rooms or buildings where highly flammable materials are kept. Fire and building regulations often include regulations restricting where and how highly flammable materials such as fuel can be stored [31].

Fire insulation is of very serious importance for the safety of human life and property. Passive fire protection allows buildings to survive for many more years and can also buy the extra time needed to escape from the structure in case of fire. The fire load of the building must also be known in order to decide how to make passive fire protection. In order to avoid life, property and psychological losses for the sake of human life, the fire load of each building construction should be calculated, and fire protection measures should be taken according to the results.

3.2. Results of indoor temperature change in living room and bedroom at the moment of experiment

During the fire, instant temperature measurements were taken in the lower-middle and top zones of the rooms. The ceilings of our fire rooms were planned to be sloped and the ceiling slope was provided with a temperature measurement datalogger from the highest

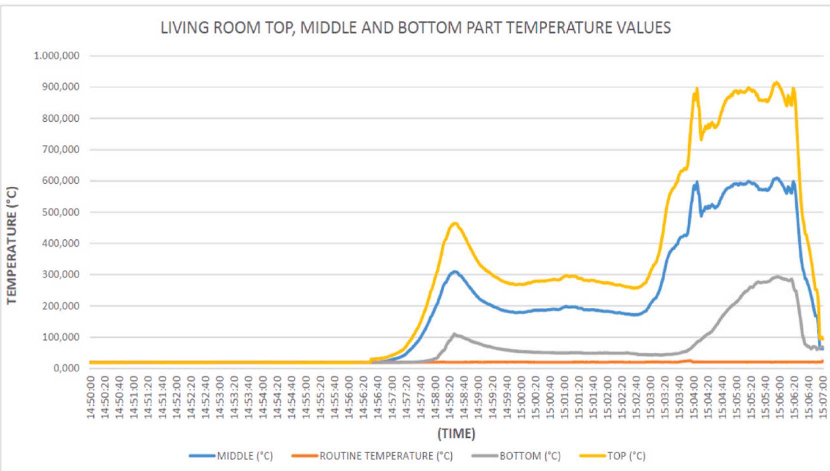


Fig. 6. Routine, bottom, middle and top zone temperature values during living room.

wall level to the lower-middle-top zones for temperature measurement in the rooms during the fire. In the bedroom, max temperatures were measured at around 1200 °C in the top zone, 800 °C in the middle zone and 400 °C in the lower zone. In the living room, max temperatures were measured at around 900 °C in the top zone, 600 °C in the middle zone and 300 °C in the lower zone.

During the fire given in Fig. 6, the top zone temperature of the living room exceeded 900 °C, while the top zone temperature of the bedroom given in Fig. 7 remained around 1200 °C.

When Figs. 6 and 7 are examined, it is seen that the temperature change curve in the lower part of the room does not form a peak when compared with the temperature change curve in the middle and upper parts. The rise in temperature causes sudden temperature increases when the burning materials reach a certain temperature and while continuing constantly at a certain temperature, sudden increases occur when new materials ignite and make serious contributions to the fire. It was observed that the heat reached its peak at the top level of all the burning materials in the room and with a certain constant due to the slope of the roof. The absence of a peak in the lower region is thought to be due to the sudden rise of the heated air and the strain on the building ceiling.

During a fire, the indoor temperature increases over time. The greatest temperature acceleration during a fire is from the beginning of the fire to the fifth minute. Human beings can only survive at about 170 °C for 1 min. That is why even seconds are crucial during a fire. Fig. 8 shows the graph of the literature fire curve and the heat values obtained from the top, middle and lower fire zones of the bedroom.

3.3. Thermal camera records

With a thermal camera, temperature measurements can be taken from walls, windows, and doors in different environments with very low error margins [32]. Surface temperature measurements on the outer wall of the bedroom are shown in Fig. 9 during the fire with the thermal camera. Measurements were taken from 4 points on the outside wall of the room at different times.

The top temperature inside the bedroom was max 1200 °C, the middle zone temperature was 800 °C and the lower zone temperature was around 400 °C, while the wall temperature outside the room was max 30.0 °C. Points SP01 and SP02 are closer to the window. SP03 and SP04 are lower in height than the other two points. It was observed at all points that the temperature increased from the floor to the ceiling in the wall temperatures outside the room as well as inside the room. It was also observed that heat concentration occurred in the window zone. Points SP01 and SP02 are closer to the window. Points SP03 and SP04 are farther from the window than the other two points. At the peak of the temperature, SP01 measured 26.8 °C while 25.0 °C was measured at SP03. While 30.0 °C was measured in SP02, 28.4 °C was measured in SP04. These data show that the temperature reached higher values in the region where the aluminum window was located. The peak temperature during the fire was after the glass had exploded.

Fig. 10 shows the surface temperature measurements during the fire on the exterior wall of the living room. Measurements were taken from 4 points on the outside wall of the room at different times.

The max. Top temperature inside the living room was 900 °C, the middle zone temperature was 600 °C and the lower zone temperature was around 300 °C, while the max. Wall temperature outside the room was 45.6 °C. Points SP01 and SP02 are closer to the window. SP03 and SP04 are lower in height than the other two points. It was observed at all points that the temperature increased from the floor to the ceiling in the wall temperatures outside the room as well as inside the room. It was also observed that heat concentration occurred in the window zone. Points SP01 and SP02 are closer to the window. Points SP03 and SP04 are farther from the window than the other two points. At the time of peak temperature, SP01 measured 45.5 °C, while 35.6 °C was measured at SP03. While 45.6 °C was measured in SP02, 37.4 °C was measured in SP04. These data show that the temperature reached higher values in the region where the aluminum window was located. The peak temperature during the fire was after the glass had exploded.

3.4. Observations before, during and after the fire

Before starting the fire experiments, Konya Metropolitan Municipality Fire Department officials were informed and were present in

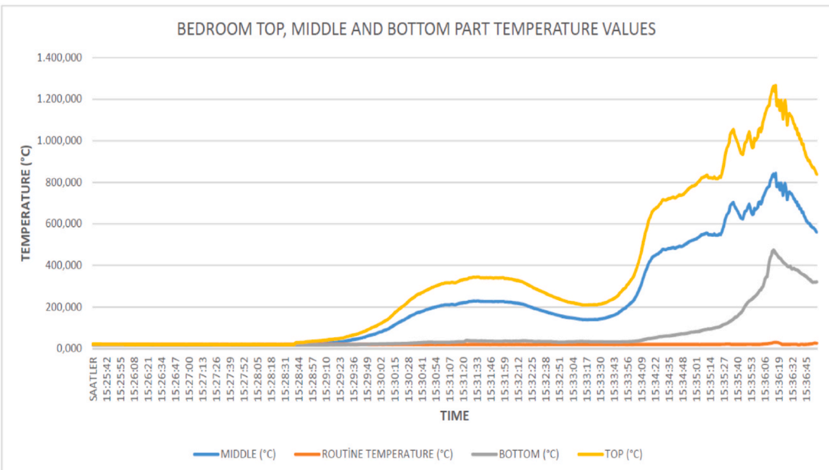


Fig. 7. Routine, bottom, middle, and top zone temperature values during fire in the bedroom.

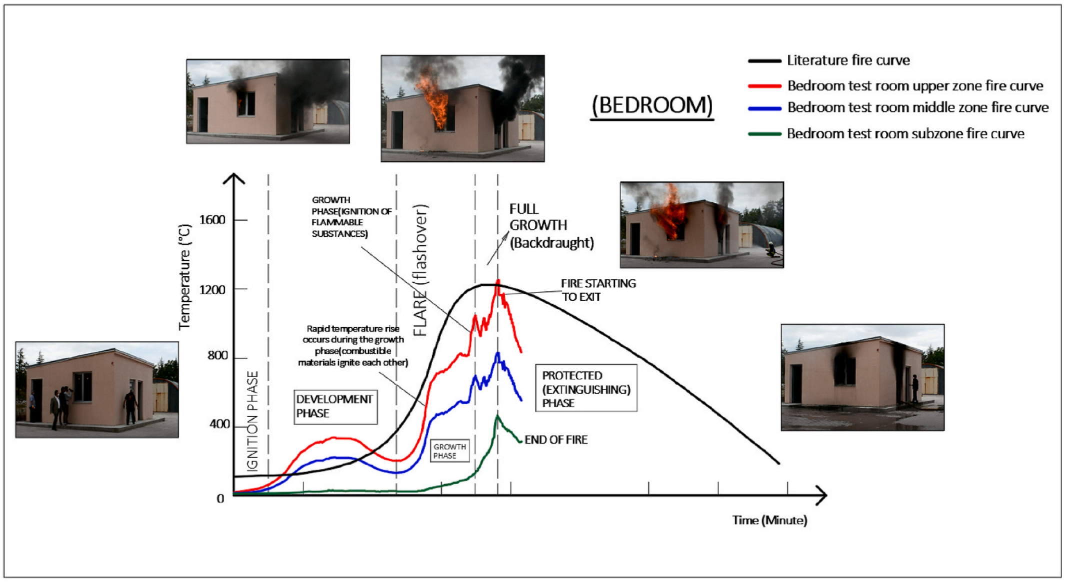


Fig. 8. Graph of the literature fire curve and the actual fire curve of the bedroom.

the experimental area before starting the experiment. After the surrounding area was secured and all preparations were completed, the starting point of the fire was determined at a point close to the center of the fire room in order to measure the heat changes more clearly, taking into account the slope of the roof and taking into account the equal distribution of heat on all sides, and a large piece of paper was burned and left in contact with the large armchair, the door was closed and the fire was started. The first fire experiment was started in the living room on June 04, 2021 at 14:55:36. Approximately 95 s later, it was observed that the first smoke started to come out of the building. In the 7th minute after the start of the experiment, the door was opened assuming that it was opened for intervention. With the opening of the door, the oxygen entering inside caused the development phase to accelerate. This process demonstrated the importance of trying to suffocate the fire in its environment. The graph given in Fig. 6 shows the increase in the heat value with the opening of the door. In the 8th minute of the fire, the window glass was broken from the upper right side. At 9 min and 44 s of the fire, an explosion occurred in the computer monitor and as a result of this explosion and internal pressure, the windowpanes were completely shattered and scattered around. After the explosion of the windows, dark, black-colored smoke started to emerge in the form of a smokeless clear flame at about 10 min. After the fire started to spread towards the roof in the form of a flame-over and after making sure that the fire had grown sufficiently, the fire was intervened at 10 min 44 s. Fire extinguishing and cooling operations were completed in approximately 3 min and 20 s. Thus, the living room fire experiment was completed 13 min and 36 s later at 15.09.12 and the necessary camera recordings and photographs were made regarding both the temperature values and the furnishings in the room regarding the destruction of the fire. The evaluation of the destruction and consequences of a real fire in such a short time and the importance of the first response of the fire brigade to the incident also show us how valuable both active and passive fire prevention systems are.

The aluminum door used in the living room melted starting from the upper left corner with the effect of fire. The effect decreased towards the lower parts of the door. If the fire had not been intervened early, it was seen that the effects would have grown and would have started to melt towards the lower parts of the door. Door glasses were scattered in the fire. The computer monitor in the room exploded in the fire. The monitor fell from its place with the effect of the explosion. The wooden coverings of the computer desk melted in the fire. Tiles were used on the living room floor. Tile material showed higher performance during the fire compared to the flooring used on the bedroom floor. The interior plaster and paint of the living room were also completely burned and destroyed. In the single and triple armchair in the living room, the fabric parts and sponges were completely burned after the fire, the iron frame of the armchair was exposed and only the skeleton system remained. The carpet in the living room was completely burnt to ashes during the fire. The floor tiles scattered and disintegrated due to the effect of heat. The canvas painting hanging on the wall was burnt to ashes in the fire and only traces of ashes remained. Electrical socket switches were melted in the fire. Books in the bookcase started to burn during the fire. However, due to the distance from the fire-starting point and the intervention time, complete burning did not occur. The bookcase was made of metal material and heat-related deformations were observed in the metal material. The fire did not reach the level to melt the bookcase. The mirror frames in the room were destroyed and the mirror was scattered. In the living room fire, the aluminum door and window plastic changed shape. The first smoke started to come out from the upper corner point of the window and the fire started to melt at the upper corner point and the effect along the vertical axis spread downwards. The door and windowpanes were completely shattered in the fire. Looking at the exterior of the window, it was seen that there was a tendency to spread towards the upper floors with the melting of the window and the breaking of the glasses. If the intervention time had been prolonged during the experiment, it would have spread to the roof elements and continued to grow, but at the time of the experiment, it was intervened without spreading to the roof. Plastic deformation was the highest in the upper corner of the handle of the door. In the room interior

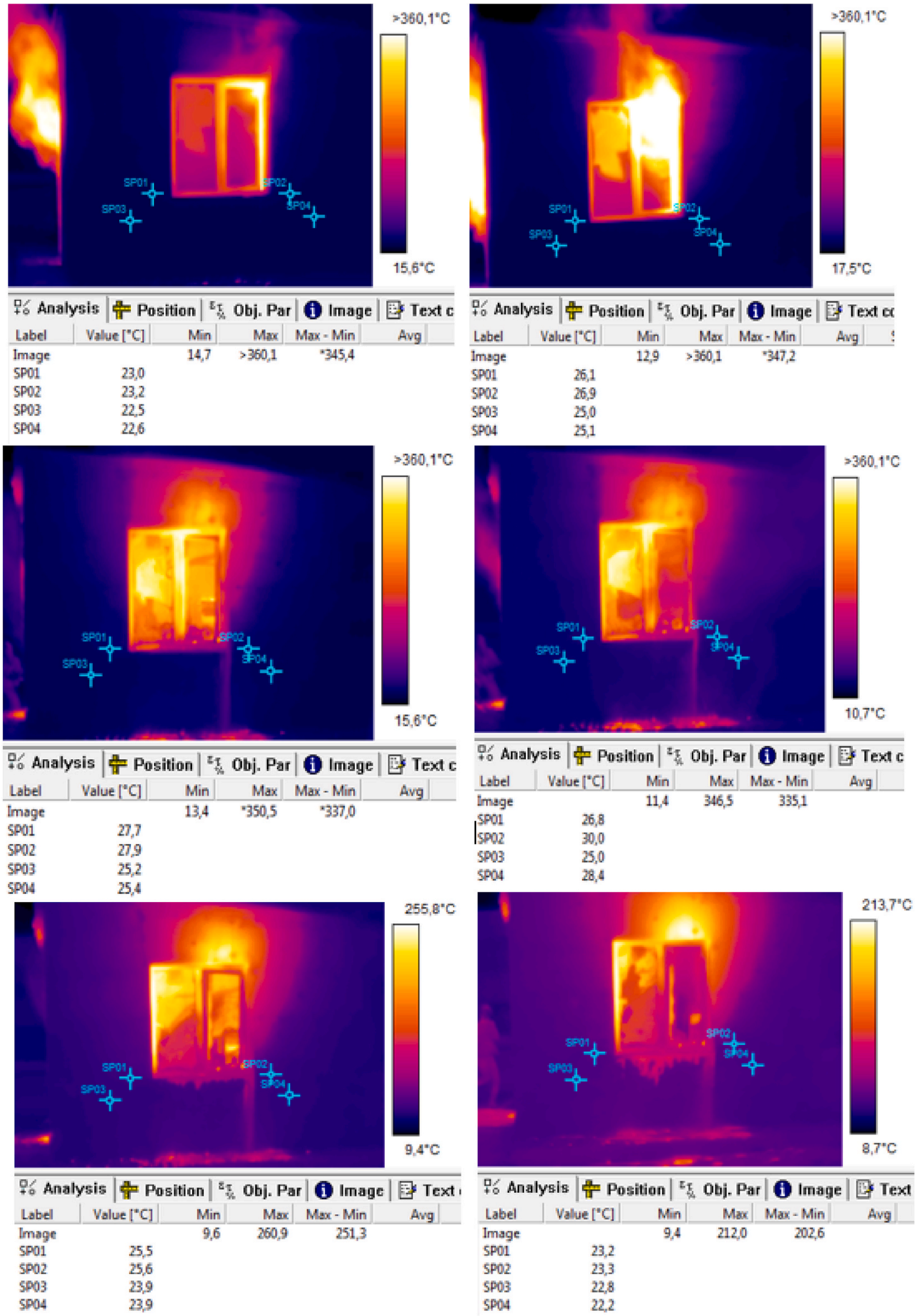


Fig. 9. Exterior wall surface temperature measurements during bedroom fire.

temperature measurements, it was observed that there was a decrease from the upper temperatures to the lower-level temperature measurements of the room. As a natural counterpart of the values in the temperature data, it was observed that the effect on the vertical axis of the door was limited towards the lower parts. It is understood that if the fire response time had been longer, the effect would

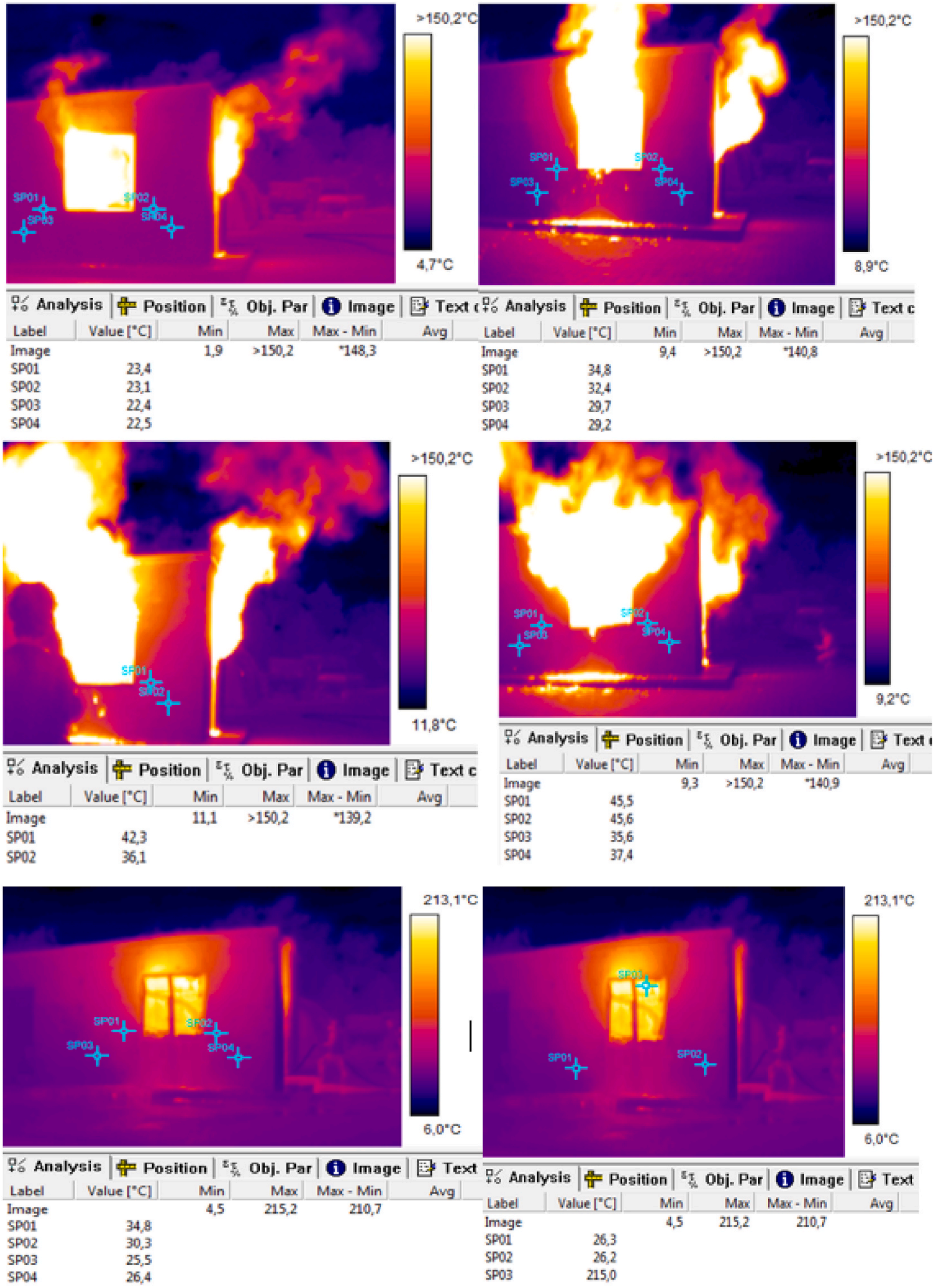


Fig. 10. Exterior wall surface temperature measurements during living room fire.

have spread more, and deformations would have increased.

After the completion of the living room experiment, the bedroom fire experiment started at 15:28:00. Approximately 50 s after the start of the experiment, it was observed that the first smoke started to leak from the bedroom window. Approximately 1 min and 35 s after the start of the experiment, the door of the room was opened and closed to fictionalize the opening of the door in possible fires. Due to this door opening and closing, a slight change in the internal temperature of the room was observed in Fig. 7. At 5 min 36 s after the start of the bedroom fire, the fire started to grow and give dark black smoke to the environment. At approximately 7 min 48 s into the fire, the windows burst and a flashover occurred. As a result of the flashover, the flame started to get rid of the smoke and spread around. Due to the spread and growth of the fire to the roof, the fire was intervened by Konya Metropolitan Municipality fire brigades in the 9th minute. It took approximately 3 min and 30 s for the fire brigades to intervene in the extinguishing and cooling processes. The bedroom fire experiment was completed approximately 12 min and 30 s later at 15:40:30. When the conditions of the wardrobe and chair materials in the bedroom before and after the fire were examined, the upper part of the wardrobe fell with the effect of the fire. The outer coatings of all furniture materials were destroyed. The interior paint in the room was also destroyed by fire. In the fire, the aluminum entrance door windows exploded. In addition, plastic deformations occurred on the upper parts of the door. During the fire, the temperature in the upper part of the room was very high and the decrease in the temperature value towards the lower parts of the room was also observed along the vertical axis of the door. Wall paintings in the bedroom were burnt to ashes. Electrical sockets melted and became unusable. Burns occurred on the laminate flooring used as bedroom floor covering.

In the bedroom fire, the headboard and the bed burned to ashes, leaving only the springs and the skeletal system of the bed. The picture board and interior plaster and paint were destroyed by fire and the wall remains in its original finished state. The electrical sockets to the right of the entrance have melted. The effect of the melting in the sockets has completely damaged the electrical cables and rendered them unusable. Roller blinds used in the bedroom were also destroyed by fire. The window started to give the first smoke from the upper corner of the window, at the same time it started to melt from this point and started to spread under the window along the vertical axis. The prolonged fire intervention time showed that the meltdown would spread to wider areas. Windowpanes were shattered and scattered in the fire and as a result, it was observed that the fire tried to grow from the top of the window to the upper floors along the facade. Although the maximum temperature value of the fire in the bedroom was higher, the partially early intervention caused no difference in the deformations. In the living room and bedroom fires, the fire tended to spread to the roof with the effect of bursting windows and opening doors. Although there were partial ignitions on the roof, the spread to the roof elements was prevented by the intervention of the fire brigade teams.

3.5. Evaluation of camera laser heat and humidity meter results

Measurements were made from the walls before and after the fire with the camera laser heat and humidity meter device. In the experiment, some readings were taken on the exterior wall temperature values after the fire in the living room. The first measurement was taken 11.39 min after the start of the experiment and 1.09 min after the end of the experiment and it was determined that the surface temperature was 14.7 °C. In the measurement made from another point of the wall, the surface temperature was 14.1 °C. The measurement made 1.52 min after the fire was extinguished from a different wall showed a measurement value of 14.7 °C. Interior wall temperature values were measured after the fire in the bedroom. In the first measurement, the interior wall temperature was 125.6 °C and this value corresponds to approximately 3.04 min after the fire was extinguished. The wall opposite the measured wall measured 81.7 °C approximately 3.28 min after the fire was extinguished. The temperature of the inner wall with the door of the experimental room was 47.2 °C 3.41 min after the fire was extinguished. In the experiment, evaluations were made by measuring the external wall temperature values after the fire in the bedroom. The first measurement was taken 12.20 min after the start of the fire experiment, the external wall temperature was 20.1 °C, which corresponds to 3.49 min after the fire was extinguished. When another point of the measured wall was measured, the wall temperature was 20.6 °C at 12.36 min after the start of the fire. This value corresponds to 4.05 min after the fire was extinguished. The temperature of the outer wall with the door in the test room was 20.4 °C 4.13 min after the fire was extinguished.

3.6. Evaluation of experimental heat measurement results

When the values obtained from the thermocouple, thermal camera, laser heat, and humidity meter devices are evaluated in general.

1. We can say that the aerated concrete wall material, which is used as wall material, and 5 cm thick rock wool insulation material have good fire resistance, both materials maintain their thermophysical properties very well, and there is no problem on the inner wall surface after the fire and it will not pose a problem in reuse. In the bedroom experiment, where the internal temperature of the room reached 1200 °C, the outer surface temperatures were measured to have an average of 25–31 °C, and similarly, in the living room, where the internal temperature of the room reached 900 °C, the outer wall surface temperatures were measured to be 41–46 °C.
2. In the measurements of aluminum door and window profiles, it was determined that slight deformations started when 500–550 °C was reached and the deformations accelerated and intensified when temperatures of 600 °C and above were reached. This is especially evident at the points where the temperature values are high.
3. When the glass surface temperature reaches 80–90 °C, it is observed that it starts to smoke from the corner and explodes and disperses in parallel with the increase in surface temperature.
4. It was determined that the plastic derivative materials in the interior of the room melted, especially the electricity and electrical cables became completely unusable.
5. It was observed that the monitor in the living room exploded with serious pressure and blew out all door and window panes.

4. Results

The whole building is sheathed with rockwool thermal insulation material. The indoor and outdoor surface temperature values of the rooms are close to each other. As a result of the study, the importance of the designer's design by evaluating the possible fire consequences in building design was emphasized. It is assumed that the problem can be solved by making the right decisions in product selection, positioning of the selected products, system maintenance and operation stages and raising awareness about which building products would be more appropriate in terms of social, economic, cultural, and psychological aspects.

It was clearly observed in the experimental study that the real-life conditions are different from the experimental results carried out in the laboratory environment. Inferences were made by monitoring every second of the system in a real building, where a 1/1 scale building is a factor that directly affects the fire load and the size of the fire, such as furnishing with different building materials, and different furnishing elements.

It is a known fact that the approximate annual burden of fires on our country's economy is more than 50–60 million dollars, and evaluations have been made on the effects of a real fire test result carried out in a controlled manner and concrete data. It has been revealed that the people who design and use the buildings should make better decisions in product selection and should be made aware of which type of building products to use in which type of spaces would be better for health. The measures that will ensure that the building has a good structural performance and that the toxic fumes caused by the fire are removed from the environment are discussed.

With the fire room experiment, a 1/1 scale fire was started and the factors affecting the beginning, formation, development, consequences and fire were handled scientifically. The creation of a real 1/1 scale experimental setup has produced results that can lead to similar studies to be carried out in the future. As a result of the fire load calculations, the fire index value of the bedroom was calculated as 1.18. A fire index value of 1.86 was observed in the living room. These values in the index suggest that there is a danger of fire spread in both rooms and even the possibility of a fire storm due to strong air flow if the fire in the living room reaches large levels in the living room.

During the fire, instantaneous temperature measurements were taken in the lower, middle and top regions of the rooms. In the bedroom, maximum temperatures were measured at around 1200 °C in the top zone, 800 °C in the middle zone and 400 °C in the lower zone. And in the living room, maximum temperatures were measured at around 900 °C in the top zone, 600 °C in the middle zone and 300 °C in the lower zone. It is clear from these results that the measured temperature increases in direct proportion as the elevation increases during the fire. While the internal temperature of the bedroom was around 1200 °C, the external temperature of the wall showed maximum temperature values around 25–31 °C. In the living room, the internal temperature was around 900 °C, while the external wall temperature was around 41–46 °C. For the bedroom fire, the external wall temperature before the fire was checked and the temperature was measured at around 21 °C. The post-fire interior wall temperature ranges from 47 to 126 °C. Looking at the exterior wall temperature measurements after the fire, 20.1–20.6 °C temperature values were measured. For the living room fire, the external wall temperature before the fire was checked and the temperature was measured at around 19 °C. The temperature of the interior wall after the fire was measured at around 130 °C. When exterior wall temperature measurements were analyzed after the fire, the measured temperature values were around 14 °C. There was a very wide range of temperature changes inside the room, whereas the temperature changes outside the wall were much more limited. The test result data shows that the aerated concrete material and rockwool insulation material used in the test rooms gave very successful results in fire transmission. In addition, after the windows and doors exploded, the rock wool stopped the progress of the fire through the facade to the roof.

It was seen that the fire could not reach its maximum level without the doors and windows exploding. Therefore, the biggest solution to prevent the fire from growing and spreading is to cut off the amount of oxygen entering as soon as the fire starts. The actions that can be taken to prevent doors and windows from bursting are of even greater importance.

5. Suggestions

The absence of a comprehensive approach to fire injury prevention is the most significant barrier to fire injury prevention, which affects many factors including the challenges associated with building structures, socioeconomic factors, human factors, as well as the challenges of combining efforts. Safety promotion, therefore, requires a comprehensive and preventive approach and also requires reforms in various sectors such as construction, legislation, culture and individual behavior.

In the room where the fire load was higher, the temperature was lower than in the other room. The results can be explained by examining this issue in more detail.

By designing two rooms with the same dimensions in 1/1 full scale, a building with identical furnishing features can be built. And while one room of this building has a fire detection and extinguishing system, the other room can be designed in such a way that it does not have any fire detection and extinguishing system.

Experiments can be carried out by placing devices that can take thermal images indoors in the experimental rooms used in the study, and as a result of the experiments, instant material temperature changes in the interior can be observed. At the same time, the fire test building can be modeled in simulation programs with exactly the same features and the same fires can be started.

During the search for new materials that are more resistant to fire, the negative aspects of existing materials should be seen, and these deficiencies should be tried to be eliminated by focusing on these weak points.

It is assumed that the problem can be solved in the very beginning by raising the awareness of building and material designers to make the right decisions in the product selection of the spaces or materials they design and which building products will be healthier to use in the buildings. Learning the fire classes of building elements and using them when designing the building is vital for the health of living beings.

In the experimental study, the fire could not reach its maximum level before the doors and windows exploded. Therefore, the biggest solution to prevent the fire from growing and spreading is to cut off the amount of oxygen entering as soon as the fire starts. Based on this idea, the experiment can be re-evaluated using fire-resistant doors and windows. And comparison can be made with the results.

CRediT authorship contribution statement

Mustafa Altın: Conceptualization, Methodology, Visualization, Writing – review & editing. **Muhammed Furkan Kılıçarslan:** Validation, Investigation, Writing – original draft, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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