

T. R.

VAN YUZUNCU YIL UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES
DEPARTMENT OF CIVIL ENGINEERING

MODELING OF BALCONY WITH THERMAL BREAK ELEMENT

M.Sc. THESIS

PREPARED BY: Zaytun Mohammed MURAD
SUPERVISOR: Prof. Dr. Mücip TAPAN

VAN-2022

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ACCEPTANCE and APPROVAL PAGE

This thesis entitled "Modeling of Balcony with Thermal Break Element" presented by Zaytun Mohammed MURAD under supervision of in the department of civil engineering has been accepted as a M. Sc. thesis according to Legislations of Graduate Higher Education on / / with unanimity / majority of votes members of jury.

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THESIS STATEMENT

All information presented in the thesis obtained in the frame of ethical behavior and academic rules. In addition, all kinds of information that does not belong to me have been cited appropriately in the thesis prepared by the thesis writing rules.

Zaytun Mohammed MURAD



ABSTRACT

MODELING OF BALCONY WITH THERMAL BREAK ELEMENT

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M. Sc. Thesis, Department of Civil Engineering
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As energy efficiency in buildings becomes increasingly important, it is necessary to accurately estimate thermal and strength properties of building parts. Thermal break components used to link balcony and inner slabs in buildings must be subjected to a transient thermal and structural study in order to achieve this aim. An insulating body developed by Inovan Yapı Teknik consisting of tension bars, and compression modules are the main components that make the thermal break element named IzoBlock. The characteristics of thermal break components has been determined based on data collected from laboratory testing of IzoBlocks in order to simulate the balcony-slab connection. Complex geometries in the models will result in load transfer and thermal breaking effects, which will necessitate more realistic two- or three-dimensional models to account for. The 3D model has been created through using Abaqus Software and a parametric study was carried to investigate the effectiveness of IzoBlock with different properties.

Keywords: Abaqus software, Displacement, High strength concrete, Isolation, Moment capacity, Thermal break, Thermal bridge.



ÖZET

TERMAL KIRILMA ELEMANI İLE BALKONUN DENEYSEL ÇALIŞMASI

MURAD, Zaytun Mohammed
Yüksek Lisans Tezi, İnşaat Mühendisliği Anabilim Dalı
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Binalarda enerji verimliliği giderek daha önemli hale geldiğinden, bina elemanlarının ıslı ve dayanım özelliklerini doğru bir şekilde tahmin etmek gereklidir. Bu amaca ulaşmak için binalarda balkon konsollarındaki ıslı kayıpların önüne geçmek için kullanılan taşıyıcı ısı yalıtılmış bileşenlerinin yük taşıma kapasitelerinin belirlenmesi gereklidir. İnovan Yapı Teknik tarafından geliştirilen, çekme çubukları ve basınç modülleri ve yalıtılmış malzemeleri, İzoBlock adlı taşıyıcı ısı yalıtılmış elemanını oluşturan ana bileşenlerdir. Balkon-döşeme bağlantısını simüle etmek için taşıyıcı ısı yalıtılmış bloğu İzoBlock'un dayanım özelliklerini, laboratuvar testlerinden toplanan verilere dayanılarak belirlenmiştir. Modelerdeki karmaşık geometrilerle yük aktarımı ve ısı yalıtılmışının sağlanmış olması, daha gerçekçi iki veya üç boyutlu modellerin hesaba katılmasını gerektirecektir. Abaqus Yazılımı kullanılarak 3 boyutlu model oluşturulmuş ve farklı özelliklere sahip İzoBlock'un etkinliğini araştırmak için parametrik bir çalışma yapılmıştır.

Anahtar Kelimeler: Abaqus yazılımı, Deplasman, Yüksek dayanımlı beton, İzolasyon, Moment kapasitesi, ıslı kırılma, Isı köprüsü.

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2022

Zaytun Mohammed MURAD



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SYMBOLS AND ABBREVIATIONS

Some symbols and abbreviations used in this study are presented below, along with descriptions.

Symbols	Description
ABAQUS (FEM)	A software suite for finite element analysis and computer-aided engineering,
1D	one-dimensional
3D	three-dimensional
E	Young's modulus
EN	Euro codes
f_{cu}	ultimate compressive strength
f_u	Tensile ultimate strength
f_y	Tensile yield strength
G1	Group no. one
k_c	Second stress invariant ratio on tensile meridian
Kn	Kilo newton

Abbreviations	Description
LVDT	Linear Variable Differential Transformer
mm	millimeter
MPa	(Mega Pascal) Primarily used for higher range pressure measurement due to its larger value
SPH	Smoothed Particle Hydrodynamics
U-value	the rate of transfer of heat through a structure
W/mK	Watts per meter-Kelvin
psi (Psi)	Pounds per square inch
ψ	Dilation angle
ξ	Eccentricity

Abbreviations	Description
σ_{b0}/σ_{c0}	Biaxial stress ratio
μ	Viscosity parameter
ν	Poisson's ratio
ϵ_y	Tensile yield strain
ϵ_u	Tensile ultimate strain



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1. INTRODUCTION

1. 1. Background

In engineering projects, thermal break defined as a thermal barrier through utilizing elements with low thermal conductivity in order to stop thermal flow or reduce thermal flow from inside of the building to outside or from outside to inside. In another meaning material with having low thermal conductivity called thermal break. Mentioned materials commonly used in building balcony to reduce thermal flow.

In construction projects or building houses there are two important things that needs to be considered, the first one is selecting balcony which is important for any buildings and the second one is selecting require materials to isolate outside environment from inside the buildings through thermal insulation (Buday, 2014). Now days, proper building differentiate with others through thermal performance characteristics. So thermal break need to be quantified to decrease heat loss as well as condensation risk (sapphire 2021).

Balcony could be mentioned as an out extension or external extension which is mostly appear in high or upper floor of hoses, buildings and typically the length is about one meter (3 feet). Creating balcony for upper floors in the buildings has a long history. So, balcony has been supported by utilizing courses of stonework as well as large wooden or stone brackets and etc., at medieval and Renaissance periods. It means, even based on historical evidences balcony considered as a basic or essential architectural element which can be detected in the residential buildings and other buildings as well (Sierra, 2013).

In another meaning, balcony is known as an extension of the buildings roofed area which is provide an easy and quick way to access external environment. Despite the fact that they might be found in structures at all scopes, their essence is more articulated in structures arranged in zones where the natural and especially the climatic conditions are gentle for extensive stretches of the year (Papamanolis, 2004).

Much focusing on the topic, the level of passing heat or heat flow relies on the thermal break elements and its factors such as

- Characteristics of the elements in terms of thermal conductivity

- Cross sectional area of the projects or buildings
- The nature of heat and how it is able to pass in or out of the buildings.

Also, there are several other important points which may produce influence on the construction projects in terms of heat transfer and other related points as shown below

- Surface conductivity as well as relative area of the buildings needs to be considered in terms of contacting source of heat and etc.
- Side heat flow is another important point which may path through the breaks and lead to transfer heat from outside to inside of the buildings or vice versa

In engineering projects and constructions there are number of materials that are used in thermal bridge design. And it can be said that, the most proper one can be differentiated with other improper thermal bridge designs based on the thermally conductive element. Basically, related to the types and characteristics of thermal bridge (Berggren and Wall 2013b). Based on the researches and studies three different characteristics level commonly utilized to evaluate and analyze thermal bridge influence or effects of thermal bridge including thermal transmittances ψ (Psi), thermal energy losses and temperature index TI as well. Generally, there are two different types of thermal bridge including (Linear Thermal Bridges and Point Thermal Bridges) (Asdrubali, Baldinelli and Bianchi 2012). Linear thermal bridge is one of the types of thermal bridge which is able to extent or distribute along thermal envelope until a certain length. This kind of thermal bridge normally used in the balcony that connected with house or buildings floors or floors slab that goes along buildings walls, edges, windows and etc. in this kind of thermal bridge (Borelli et al., 2020), linear thermal transmittance used to describe linear thermal bridge energy loss. Figure below represent the linear thermal bridge model (Capozzoli and Corrado, 2013).

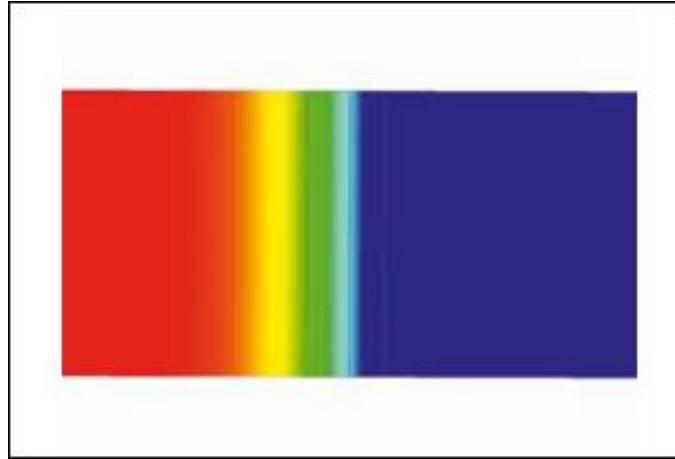


Figure 1.1. Linear thermal bridge model.

On the other hand, the second types of thermal bridge known as a Point Thermal Bridges. This kind of thermal bridge commonly used in specific areas in the buildings and it can be characterized by Point thermal bridges. In addition, this type of thermal bridge only appears in one spot which is appear in curtain wall supports as well as anchors that enter the separating layer. In this kind of thermal bridge Point thermal transmittance χ typically used to describe energy loss shown in below figure (Schoeck, 2018), (Capozzoli et al., 2013).

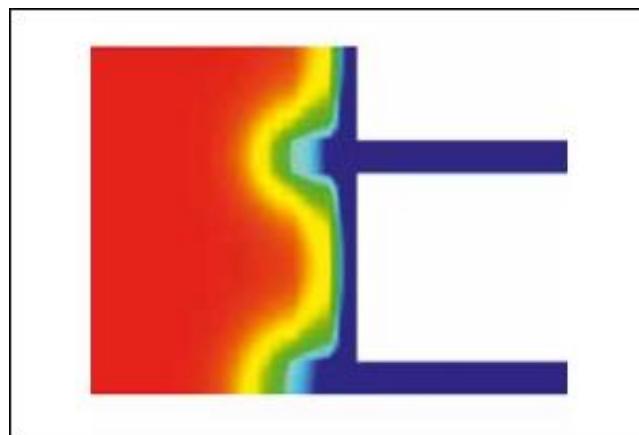


Figure 1.2. Energy loss in balcony (Schoeck, 2018).

The largest energy consumer in the unite state and Canada is building sector, based on data up to 40 percent primary energy use. Due to that, rising energy efficiency in the buildings is very essential and necessary. To increase energy efficiency of buildings and

meet the required level building envelope thermal mentioned as a proper consideration for meeting the required target (Haddock and Roppel, 2013).

Moreover, there are three different ways thermal or heat can move through the structure components including conduction, convection and radiation. In thermal bridges thermal or heat transfer by conduction. So, the movement level or rate evaluate by variation of temperature at each end of the thermal bridges and well as evaluated through materials thermal conductivity characteristics used in thermal bridge (Motahayyer and Samimi-Akhijahani, 2019).

An insulating body developed by Inovan Yapı Teknik consisting of tension bars, and compression modules are the main components that make the thermal break element named IzoBlock. The characteristics of thermal break components has been determined based on data collected from laboratory testing of IzoBlocks in order to simulate the balcony-slab connection. Complex geometries in the models will result in load transfer and thermal breaking effects, which will necessitate more realistic two- or three-dimensional models to account for. The 3D model has been created through using Abaqus Software and a parametric study was carried to investigate the effectiveness of IzoBlock with different properties

1.2. Problem Statement

Thermal bridges, which are exposed concrete balcony-slab connections, are responsible for a substantial amount of energy consumption. It is possible to find a cost-effective alternative, but these solutions are typically ruled out due to aesthetics, constructability, or sequencing issues. Few successful projects have been completed in the globe that use these goods, but more are on the way. An assessment was made of the effects of balconies on the effective heat flow and indoor thermal comfort (Murad and Ramakrishnan, 2015). Energy loss from open balconies was quantified, as well as space conditioning savings that may be realized when balcony and slab edge thermal break items are employed in typical circumstances.

1.3. Aim and Objective of the Research

The following are the main objective remarks of this study:

1. Conduct an intensive simulation study to create an effective balcony slab using ABAQUS (FEM) and the standard numerical techniques.
2. Investigate the strength of load bearing thermal insulation block developed by İnovan Yapı Teknik and named as IzoBlock.
3. Conduct a parametric study to provide a cost-effective solution to the problem of thermal bridge.

1.4. Research Significance

Total building energy savings can be predicted to be high due to the fact that structural thermal break components have a lower thermal conductivity than non-insulated connections. Using a finite analysis program to simulate different structural element to use in balcony and to determine the optimum design method to have high strength capacity balcony slab and minimum concrete area in thermal bridge region.

1.5. Thesis Outlines

CHAPTER 1 → Introduction.

CHAPTER 2 → Literature Review.

CHAPTER 3 → Research Methodology.

CHAPTER 4 → Result & Discussion.

CHAPTER 5 → Conclusion & Recommendations.

2. LITERATURE REVIEW

Thermal bridge could be mentioned as localized areas with having advanced thermal conductivity than the adjacent areas. Having thermal bridge in the buildings will result in having advanced temperature transfer through the assembly and colder surface temperatures on the warm side of the assembly. A thermal bridge may lead to produce concentration on cold surfaces, which could lead to:

Higher energy use for warming and higher energy use for cooling, rebelliousness with Building Regulations, uneasiness because of cold surfaces, consumption of metal components and design, rot of wood-based materials, apparent examples on inside or outside surfaces because of varieties of surface temperature and drying potential, debasement of protection execution (in the event that buildup happens inside the construction), form development and related wellbeing concerns (O'Grady et al., 2018).

As it's clear, the level of energy of the building include 40 percent of primary energy utilization and 24 percent of the generation of greenhouse gases around the world (Khatib, 2012). The altered of the new European plan states that by the end of 2020 all recent construction projects shall be built as "nearly zero-energy buildings". An almost zero-energy building is characterized on premise of energy productive methodology and in addition the low measure of required energy ought to be covered particularly from environmentally friendly power sources. Also, energy investment funds rely upon entire structure envelope and its presentation (Gawin and Wilkes, 2004) (Kosny and Desjarlais, 1994). Buildings that planned based on such principles; the major amount of demand for heating is produced by heat transmission between building components and thermal bridges. It is accordingly urgent to ascertain the hotness move by a right way with right suspicion of warm scaffold event. To that end many creators have called attention to the need of precisely surveying all structure subtleties structure warm viewpoint perspective (Ingeli, 2014). On the other hand, wrongly determination process may lead to underestimation of warming systems, indecisive indoor climate and finally, additional costs for heating that exceed our moulds. In general, the heat flow through the building component is considered to be of the one-dimensional (1D) type (Clarke and Maver, 1991). For instance, it is expected to be in the way perpendicular to the wall. It causes the

fact, that the heat conductance and temperature differential in this direction are much greater than that in the lateral instructions. However, localized multi-dimensional heat conduction through the building envelope is more realistic. In reality, thermal bridging develops the inner surface heat faster to the environment heat on the other side, and lead to produce higher heat stream between those conditions. While the inside surface temperature ought to be considered in a build-up hazard evaluation during warming season, higher hotness stream rate ought to be considered during the plan of structures and their all year ecological control frameworks. Warm scaffolds will bring the interior surface temperature closer to the climate temperature on the opposite side, and causes higher hotness stream between the two conditions.

Different places around the world utilize different calculation ways of thermal bridges. In Sweden, the impact of thermal bridges may be accounted for by increasing calculated transmission heat transfer through building elements by 20%, regardless of building system used ((Mata and Kalagasidis, 2009)). In Finland, a simplified method is used where the effect of thermal bridges usually is included in the calculated transmission heat transfer through building elements by weighting thermal conductivity of different materials (Berggren and Wall, 2013a). Simplified methods may be incorrect. The transmission heat transfer losses due to thermal bridges may increase when more insulation is used in exterior walls (Berggren and Wall, 2018). From the energy saving point of view and the issue of moisture condensation at inner surfaces. A balcony slab represents generally one of the most significant elements of the whole building envelope (Wakili and Frank, 2007). Especially due to the fact that balcony slab passes through the building envelope and connects the internal and the external environment. In other words, it results in a thermal bridge which can be quantified by an additional heat loss and by reduction of the temperature at the inner corners. This article shows that with the introduction of balcony thermal break, the overall heat transfer at balcony slab is significantly reduced and the interior floor surface temperature is greatly increased under typical winter design conditions.

Thermal Break

The function of thermal break is to provide a good condition through preventing heat flow. In some researches and studies, it has been mentioned as a layer of insulation, and in order to have a proper insulation high conductivity materials will not be used for this purpose. There are several examples for continuous insulation in the buildings or construction projects rigid board insulation is one of them. In addition, there are several features of continuous insulation as mentioned in the below points

- it is able to slow down the movement or heat or heat transfer in the buildings materials and elements
- it is able to increase buildings envelope performance
- It is a proper way to get or reach proper energy adeptness with providing well inhabitant comfort stages.

Depending on the construction projects the minimum or lowest level of envelope performance needs for buildings walls, roofs as well as floors, which is selected by rules in Unite Arab Emirate. With some other requirements such as utilizing new and repaired air-conditioned buildings. Moreover, there are several things which are very important in thermal bridge like the interface or connection between concrete, walls, beams and other points which may let heat transfer. Due to that, mentioned points need to be insulated very well to decrease transferring heat around the buildings in to the buildings(Kingspan, 2020).

Transferring heat contribute to a very serious problem in construction projects or buildings. So, many papers and studies focused on using thermal break in construction project in order to reduce heat transfer. Many studies focused on utilizing thermal break on the balcony slabs with advance determination of thermal performance of elements that used as a thermal break. in this project Specific instances of usually utilized thermal break in structures are noticed identified with multi-dimensional and parametric methodology of displaying. As a result of thus studies, thermal bridge in the construction projects has a specific influence on seeking heat (demand). Also, researchers claim that types of construction as well as buildings geometry affect the thermal transmission and its level as well. Also based on research calculation buildings thermal conductivity and balcony

slab performance Disturbed due to low conductivity thermal break elements (Buday, 2014).

Based on European Union plan, new buildings in Europe need to be built as “nearly zero-energy buildings”. Mentioned types of building known as a building with less required energy which is rely on the buildings performance and buildings envelope as well (Kosny and Desjarlais, 1994), (Ingeli et al., 2014).

In terms of energy saving perspective and the issue of dampness or moisture consideration at inward surfaces, a balcony section addresses commonly one of the main important of the entire structure envelope particularly because of the way that balcony goes through the structure envelope and interfaces the interior and the outside climate (Wakili et al., 2007).

Depending on other studies, in order to design a proper balcony slab number of roads as well as each of them diameter along balcony requires to be known and considered as well. This action provides a good and useful heat loss analysis with showing the amount of temperature change at the inner edges of the buildings.

Thermal bridging

Thermal bridging is one of the most common building envelope efficiency issues. The balcony slab link is a typical thermal bridge in the building envelope of mid- and high-rise residential buildings (Susorova and Skelton, 2019a). Due to increased heat loss in the winter and heat gain in the summer, these balcony slab contacts are often not thermally broken, resulting in low building thermal efficiency and increased energy consumption (Buday and Vavrovič, 2014), (Finch and Hanam, 2014). Another problem with balcony slab connections is that cold indoor floor slab surfaces around the building perimeter can cause occupant thermal discomfort in the winter (Susorova and Skelton, 2019b). Thermal breaks or insulated concrete curbs are one of the most commonly suggested solutions to the balcony slab thermal bridge challenge (Murad et al., 2015). The balcony is separated from the floor slab by thermal breaks, which are thermally insulating components incorporated in the construction that mitigate heat transfer across the relation.

Thermal breaks are made up of thermal insulation between concrete slabs and structural support attached to the floor and balcony slab reinforcement bars. Extruded polystyrene, extended polystyrene, and mineral wool are common insulation products, both of which have identical thermal conductivity (0.025–0.040 W/mK) (Goulouti, 2016). Standard rebar steel or less thermally conductive stainless steel may be used for structural strengthening. Thermal breaks do not entirely prevent heat transfer through the balcony link (high concentrations of heat transfer can also occur through the metal reinforcement, which can consume 10%–20% of the cross-sectional area (Ge and Zhang, 2013)), but they can significantly minimize heat transfer through the remaining 80%–90% of the concrete slab area. The reinforcement bar diameter, the number of structural elements, the exterior wall U-value, and the size of balcony slabs all influence thermal break efficiency. To date, some research has been done on improving thermal break efficiency by using structural reinforcement made of aramid fiber (Goulouti, 2016) and fiber-reinforced polymer (Wakili et al., 2007).that is less thermally conductive than stainless steel reinforcement. Though balcony thermal breaks are a popular energy-saving technique in Europe and Canada, they are still relatively new in the US industry. Many observations of the effects of balcony thermal breaks have relied on simulations, although a limited number have relied on experimental tests under monitored conditions, such as using a hot-box apparatus. It is important to model thermal bridges using the most reliable methods by using a simulation technique. The related U-value method (in which thermal bridges are modeled as part of a weighted average-value for the whole envelope) and the direct three-dimensional modeling method are the two most widely used approaches for modeling thermal bridges (i.e., where thermal bridges are explicitly drawn on envelope surfaces with actual dimensions and material properties). Sees models, however, do not estimate building energy efficiency as well when thermal bridges are present. For ge et al. (Berggren and Wall, 2018) discovered that when forecasting the effect of balcony slab thermal bridges in multifamily high-rise buildings with concrete structures, it is best to use the three-dimensional heat transfer technique. Many studies have looked at the impact of incorporating balcony thermal breaks on the total energy usage of a home. Ge et al. analyzed thermal changes to various balcony relation specifics and their effect on overall building energy efficiency for case studies with and without balcony thermal breaks in different Canadian climates using a simulation-based analysis. Thermal breaks in balcony

ties, according to Ge et al., will theoretically minimize annual heating energy demand by 5–11 percent (Ge et al., 2013). Baba et al. observed that including thermal breaks in balcony connections would theoretically reduce annual heating energy consumption by 7–8% while increasing annual cooling energy consumption by 4–12% for the same temperature environment, and that the effect would vary depending on the climate, window range, and adjacent wall styles (Berggren and Wall, 2018). In the Chicago climate, (Haddock and Roppel, 2013). observed that balcony thermal breaks could minimize annual building energy consumption by 7.3 percent (Haddock and Roppel, 2013). Reducing thermal bridges by balcony links often aids in improving building occupants' indoor thermal comfort. When balcony thermal breaks are used in buildings situated in cold climates, Finch et al. find that indoor balcony slab temperatures can be raised by 4–7 degrees Celsius (Finch et al., 2014). tested balcony contacts with thermal breaks in a hot-box apparatus and discovered that including balcony thermal breaks would help raise the indoor slab temperature by up to 8 degrees Celsius (Susorova et al., 2019a). Insulated concrete curbs, an alternative solution to the balcony thermal bridge issue, can also boost indoor slab conditions by increasing the temperature by around 4 degrees Celsius. Given the aforementioned advantages of reducing balcony thermal bridges, it's necessary not to exaggerate the energy and expense savings associated with doing so.

The financial feasibility of the balcony thermal break solution, as stated by (Evola, Margani and Marletta, 2011), is also important to note (Evola et al. 2011). The removal of envelope thermal bridges is an effective measure to minimize heating energy consumption, but it is not always economically feasible due to long payback periods (18–20 years), according to this report, which evaluated the economic feasibility of correcting envelope thermal bridges in mild climates. Despite the body of research that has been done to date, there is very little quantitative data on how thermal breaks affect in-situ building thermal efficiency and/or overall energy consumption. This research aims to close this knowledge gap by testing the effects of balcony thermal breaks using (i) field measurements of balcony slab and surface temperatures in a real-world building in the United States, as well as (ii) 2D thermal modeling and whole-building energy simulations in the same building, as well as in many more generic building designs with simplified geometries.

The Structure and Elements of a Balcony

Balconies are cantilever structural elements of buildings. Their construction varies depending on the supporting structure of the building to which they are attached, but they are typically built by extending the slab between two levels (floors). A typical concrete balcony consists of a 15-cm-thick slab with reinforcement that extends from the adjacent strongly fixed slab of the supporting framework. Balconies supported by metal girders are made up of a series of horizontal metal girders that are approx. 10 to 15 cm thick, which often serve as an extension of the horizontal girders in the adjacent floor level, and the gaps between them are filled with small ceramic slabs of concrete slabs. Similarly, in the case of a wooden supporting frame, the balcony is supported by wooden beams with gaps filled in between. by means of planks Because of the moments provided by the loads they carry, the duration of these estimates is limited and, in any case, is determined by the design of the supporting structure. Balconies rarely exceed 2.5 meters in length in traditional buildings with a concrete or metal supporting frame, which make up the majority of multi-story buildings. This is a semi-empirical limit that satisfies their simple and relatively low-cost construction while still falling within the tolerable vibration range when variable loads are applied. Since wood is a weaker material, wooden balconies are usually narrower. Balcony floors are built on top of the supporting structure's final surface with materials appropriate for outdoor use (e.g. ceramic tiles, marble, terrazzo). Their surfaces are slightly slanted to aid in water drainage. Additionally, they are built at a lower level than the indoor floors to prevent water from flooding through the building's interior. A balcony floor with openings close to the building's façade that are covered with a grating to allow air to pass vertically over the building's surface is a relatively uncommon form of balcony floor. Aside from the horizontal floor, every balcony has a 1.10 m high parapet along its outer edge, which prevents anyone who uses it from falling off. The parapet, which is usually a supplemental feature of the balcony's main structure, may be made of a variety of materials and take on a variety of shapes. Where the building material is wood or metal, they are usually in the form of railings. On the other side, they are normally sturdy whether they are made of concrete or stone. The use of a metal frame to support extremely durable glass panes with varying degrees of transparency as facing panels is a more recent variant. Finally, even on the same balcony, parapets can take on

a number of different shapes and materials, typically a combination of solid and semi-permeable components. Balcony doors are one structural feature of a building that is directly linked to balconies. Residents must have access to their balconies by at least one balcony door. Furthermore, the inclusion of balconies in front of openings in a building's shell encourages the use of balcony doors rather than plain windows. The fact that a balcony door opening has approximately twice the surface area of a window of the same width indicates the form of indirect effects balconies have on the environmental and energy behavior of the buildings to which they belong. In non-insulated cantilevered elements, like balconies, the contact among the regular thermal bridge and the stuffs that utilized for thermal bridge leads to major heat loss, see Figure 5. Cantilevered balconies and exposed slab edges mentioned as the major serious thermal bridges in a building envelope. Non-insulated cantilevers lead to produce heat loss and meaningfully decrease the inner surface heat. As an outcome, the hazard of mould development really rises around the intersection of the interior slab and the exterior wall assembly, see Figure 6.

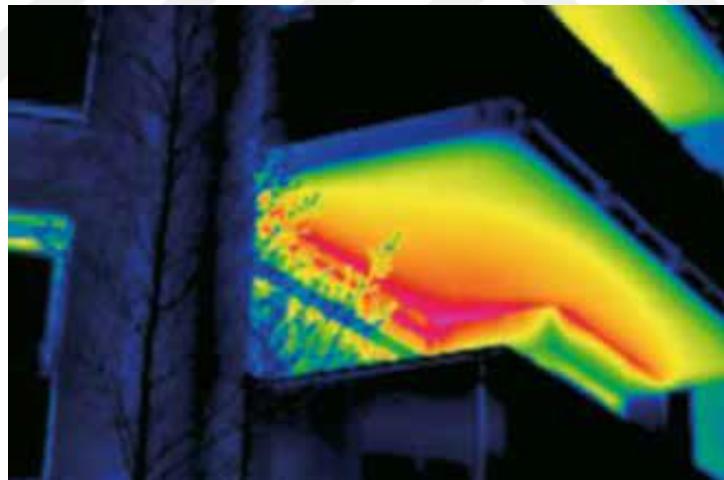


Figure 2.1. Infrared scan of a balcony thermal bridge with higher temperatures at the exterior slab. (<https://www.schoeck.com/en-gb/structural-thermal-bridges>).



Figure 2.2. Photograph showing mould growth on the ceiling of a concrete slab adjacent to an exposed slab edge thermal bridge. Condensation forms here frequently as a result of colder interior surface temperatures.
 (<https://www.schoeck.com/en-gb/structural-thermal-bridges>).

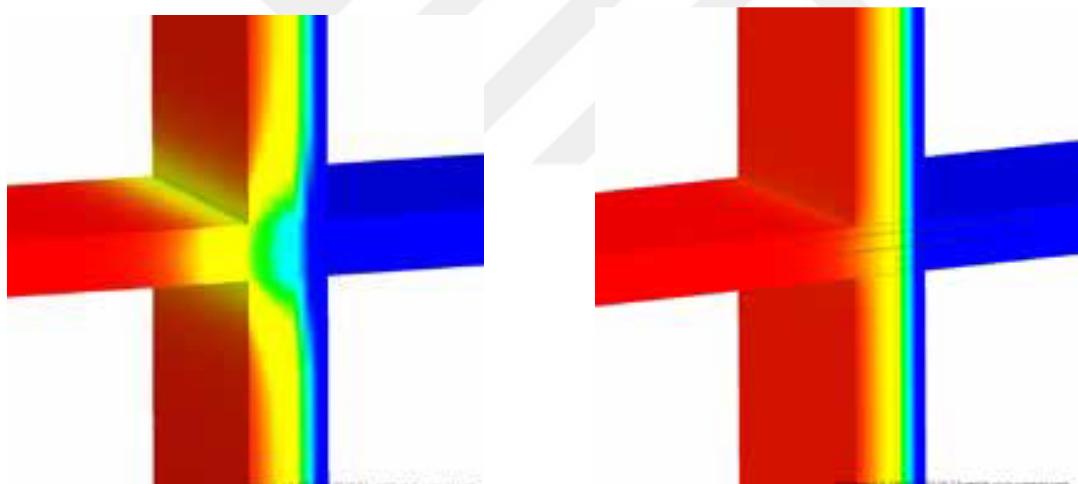


Figure 2.3. Continuous balcony slab compared with a solution with Schöck Isokorb®; Left: continuous balcony slab without thermal break, Right: Balcony slab thermally broken with Schöck Isokorb® providing a continuous insulation layer. (<https://www.schoeck.com/en-gb/structural-thermal-bridges>).

Figure 7 illustrate the demonstrated heat delivery through a reinforced concrete balcony with and without a thermal break. Left image illustrate an absolute thermal bridge. And the color of the figure represents the process of heat flows to the outside through the balcony slab, from red to blue which means warm to cold area. On the other hand, right image represents thermally broken balcony joining. As the figure shows, a

load-bearing heat insulation element greatly decrease heat loss and provides steadiness in the insulation layer. (Thermal_Bridging_Guide_Schoeck_Isokorb [5993]).

Influences of Balconies on the Environmental Behavior of Buildings.

Influences on the physical appearance the faces of a building without balconies are flat and vertical. Although the building may be made up of a variety of flat vertical surfaces spaced at various distances and possibly with different orientations, the overall impression is of a prismatic structure. The inclusion of balconies on the building's exterior helps to break up the prismatic look. It brings variety and lightens it up. Indeed, since balconies often include a variety of other artifacts and accessories in addition to their structural elements, their impact on the overall appearance of the building to which they belong is even greater. These findings show the first and most visible effect of the existence of balconies on a building's façade: a change in the geometrical features and, eventually, the shape of the structure. The degree to which these aspects are changed, of course, is determined by the number and size of balconies in the building in question, as well as the proportion of the total surface area of the building's faces that the balconies occupy. Even if this proportion is minimal, the balconies have a catalytic effect on the overall visual effect. Balconies are a common feature of building facades in places where the climate allows for them. Balconies are an important feature of all residential buildings in Greece, which has a Mediterranean climate. At least one balcony in the shape of a projection will be available to all apartments above ground level. Indeed, more than one balcony, or even continuous balconies, will often occur, taking the majority of the building's surface area. Balconies in Greek residential buildings vary in width from 0.5 m (in the case of secondary balconies) to approximately 2.5 m. The balcony's width is often expanded further by adding a portion of the apartment's roofed area into it (Irina et al., 2019).

3. MATERIALS AND METHODS

All the procedures and supplies needed to conduct these different simulations are included in this section, as well as the description of the methodologies utilized in this research.

3.1. Software Description

The numerical analysis performed through utilizing Abaqus, which is known as one of the programs that used to determine several proposed methods to solve thermal bridge problems. Abaqus is also known as one of the proper computational software to predict or forecast 3D load-displacement, pollution spreading and comfort guides in and around buildings of all types and sizes. There were viewed as the specific places of steel support carried out in balcony slab. Every component of balcony was contained in the computation (steel support, front of overhang piece hindered by a warm break, froth parts, and warm protection of overhang section). In addition, Movement through point thermal bridges can only be retrieved through 3D fixed element modelling, since their complex nature does not permit simpler approaches as are usually assumed with linear thermal bridges. For the purpose of this thesis, Modeling of balcony with thermal break element system is selected and examined under steady-state thermal conditions using finite element analysis Abaqus. The major significant parameters the can be analyzed during design process of balcony with thermal bridge schemes are examined in order to count the influence of point thermal bridges on the unwanted displacement. Under exact applied load. The materials characteristic and size influence on the physical parameters of simulated balcony and compared with the results taken from practical test in lab.

3.2. Define Materials

This chapter describes how to define materials in Abaqus and contains brief descriptions of each of the material behaviours provided. Further details of the more advanced behaviours are provided in the Abaqus programs.

The ultimate compressive strength (f_{cu}) of IzoBlock for the simulations is ranged between 35 to 75 MPa. Balcony yield strain is 0.0044 while ultimate strain is 0.008. All other parameters are shown in (Table 3.1) including Physical constants defined and plasticity parameters. Steel properties are as shown in (Table 3.2). including inelastic (or crushing) strain, cracking strain, compression damage and tension damage.

Table 3.1. Physical constants defined in the finite element program

Absolute zero	-273.15 °C
Acceleration of gravity	9.8066 m/s ²
Atmospheric pressure	0.10132 × 10 ⁶ Pa
Stefan-Boltzmann constant	5.669 × 10 ⁻⁸ W/m ² °K ⁴ where °K = °C + 273.15

Table 3.2. Steel properties

Approximate properties of mild steel at room temperature	
Properties	SI unit
Conductivity	50 W/m °C
Density	7800 kg/m ³
Elastic modulus	207 × 10 ⁹ Pa
Specific heat	460 J/kg °C
Yield stress	207 × 10 ⁶ Pa

The properties of the steel and concrete materials used in this model are shown in Table 3.3 & 3.4 Since there is no standard data for the input values in *Abaqus* for Concrete damaged plasticity model, the reliability of input data is important.

Table 3.3. Material properties of concrete

Elasticity parameters	Young's modulus, E	26700 Mpa
Concrete damage plasticity (CDP) parameters	Poisson's ratio	0.2
	Dilation angle, ψ	31°
	Eccentricity, ξ	0.1
	Biaxial stress ratio, σ_b/σ_c	1.16
	Second stress invariant ratio on tensile meridian, k_c	0.67
	Viscosity parameter, μ	0

Table 3.4. Material properties of steel reinforcement

Elasticity parameters	Young's Modulus, E	2.1×10^5 Mpa
	Poisson's ratio, ν	0.3
Plasticity parameters	Tensile yield strength, f_y	435 MPA
	Tensile yield strain, ϵ_y	0.0021
	Tensile ultimate strength, f_u	580 Mpa
	Tensile ultimate strain, ϵ_u	0.12

3.3. IzoBlock Description

Steel plate connects to steel bar (High strength reinforcement bar). This plate used in purpose of shear capacity; the dimension of plate is 4cm x 9.8cm (W*H) cm with a thickness of 3mm (T) mm as show in (Figure 3. 4). The lower part of steel plate has been geared with 3.3 cm depth in order to avoiding the discontinuity in high strength concrete cube 5cm * 5cm.

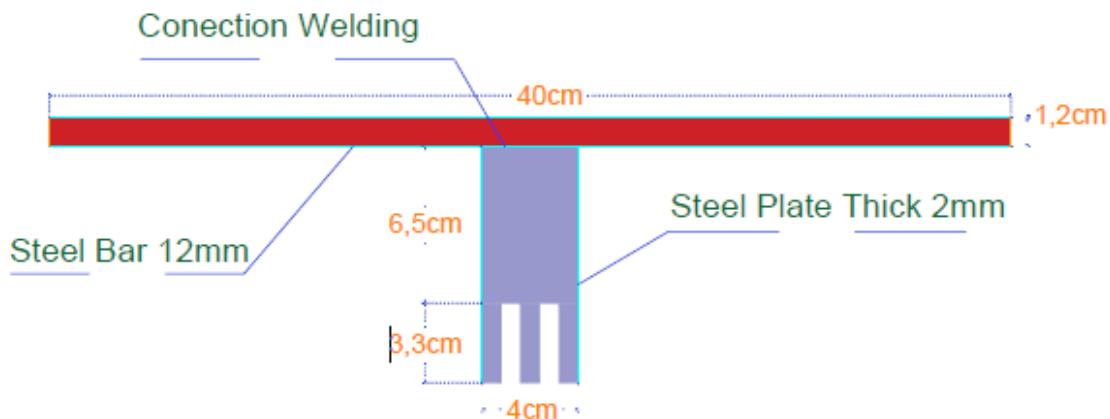


Figure 3.1. Steel plate connected by welding to high strength stainless steel reinforcement bar.

The dimension of each high strength concrete specimen is 5*5*12 cm duo to table (3) as shown in (Figure 3.2).

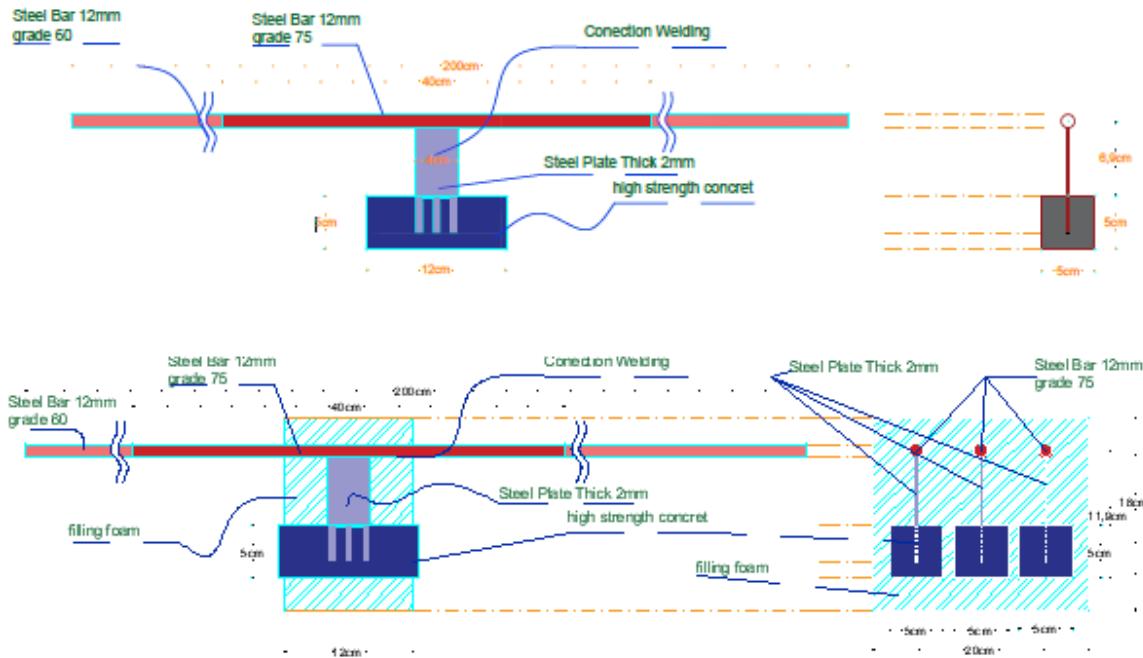


Figure 3.2. Geometric properties of IzoBlock used in this study.

3.4. Description of the Model

In this study two types of models were prepared: a balcony with IzoBlock and conventional balcony. The first one was Normal Concrete Balcony model and Abaqus software has been used to create mentioned model. The dimension of sample balcony was (1 m width, 1.2m length) and total length balcony with floor and support was 2.5 m.

The second one was the balcony with load-bearing thermal break element named IzoBlock. It can be said that, the problem examined in this research comes from an experimental project, which refers to the large overhanging balcony with a width of 1m. For the building effect, the overhang length is planned to reach 1.2m in order to determine the vibration frequency of the overhanging construction, this research utilize ABAQUS software to perform nonlinear finite element determination of the cantilever construction, and obtains the main factors affecting the load displacement value of the cantilever structure through applying required methods as well as provide reasonable suggestions for design.

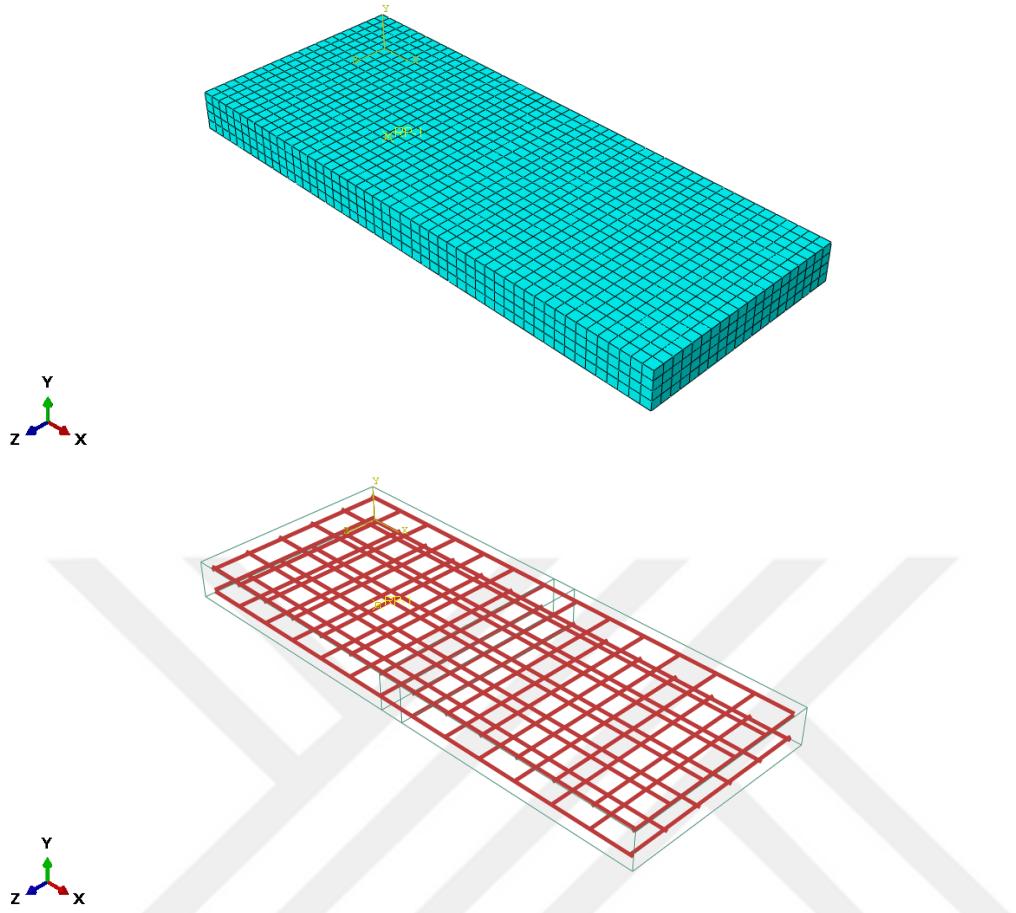


Figure 3.3. Normal Concrete Model Balcony slab using Abaqus Software.

The process goes through several stages; the first one was choosing a small overhang size of the cantilever balcony board for modelling analysis. The length of the fixed side of the cantilever board was 1.0 meters, the cantilever length was 1.2 meters, the board thickness was 180 mm, and the concrete cover layer thickness was 25mm. The section size and reinforcement are shown in (Figure 3.4).

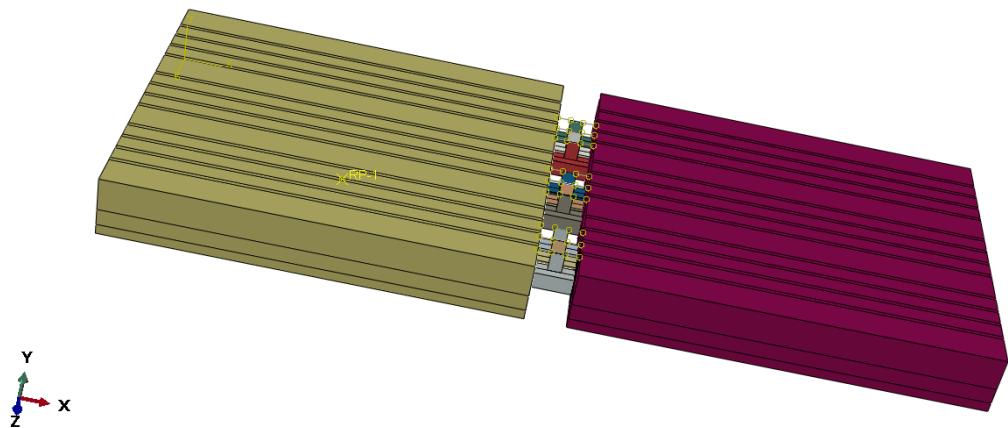


Figure 3.4. IzoBlock thermal break model in concrete balcony slab using Abaqus Software.

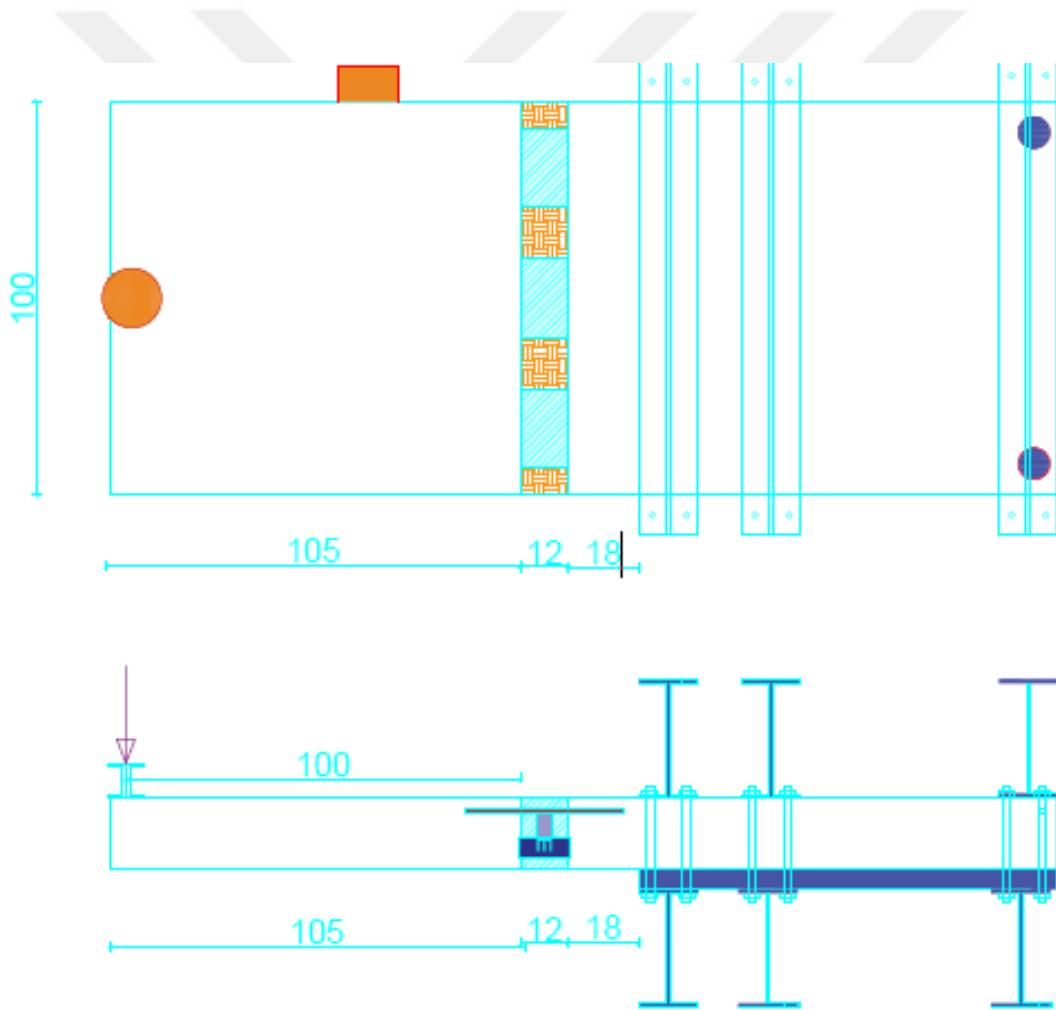


Figure 3.5. Sectional dimensions and reinforcement of balcony panels.

When meshing with ABAQUS, the diameter of the reinforcement was achieved by changing the cross-sectional area of the cantilever element. The force steel bar $\varphi 12 @ 200$, and the distribution bar set to $\varphi 12 @ 200$.

The connection between the reinforcement and the concrete realized through the interaction of the built-in area settings, with the boundary condition being fixed at one end and free at the other edges. The finite element ABAQUS model shown in (Figure 3.6).

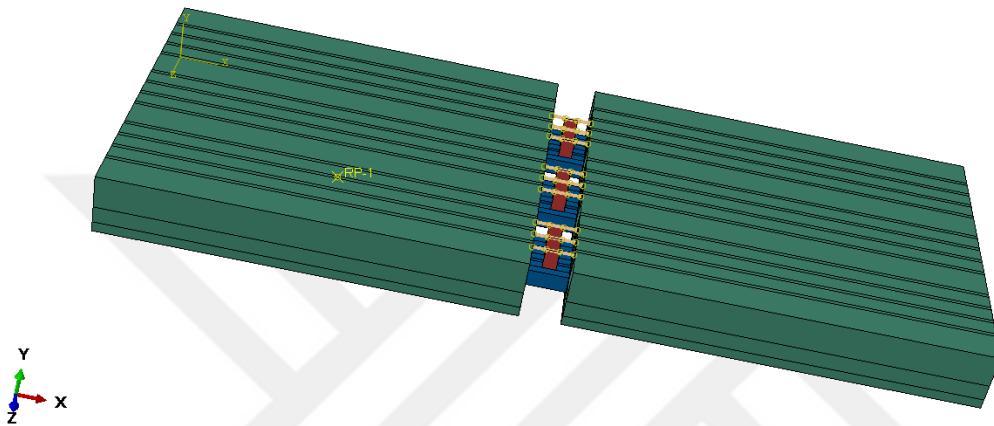


Figure 3.6. finite element ABAQUS model.

The reinforcement of inner and outer of balcony specimen has been designed according to Eurocodes (EN 1992-1-1, 2004), (EN 1993-1-1, 2005) and (EN 1993-1-4,2006)(Lennon and Moore, 2007). The grade 60 steel bar with 12 mm diameter were used to resist the applied load. Three IzoBlocks have been installed in the big balcony samples. The space between IzoBlocks filled with a wool isolation which has thermal conductivity value of 0.035 w/mK according [TS EN 13501-1/Class A.]

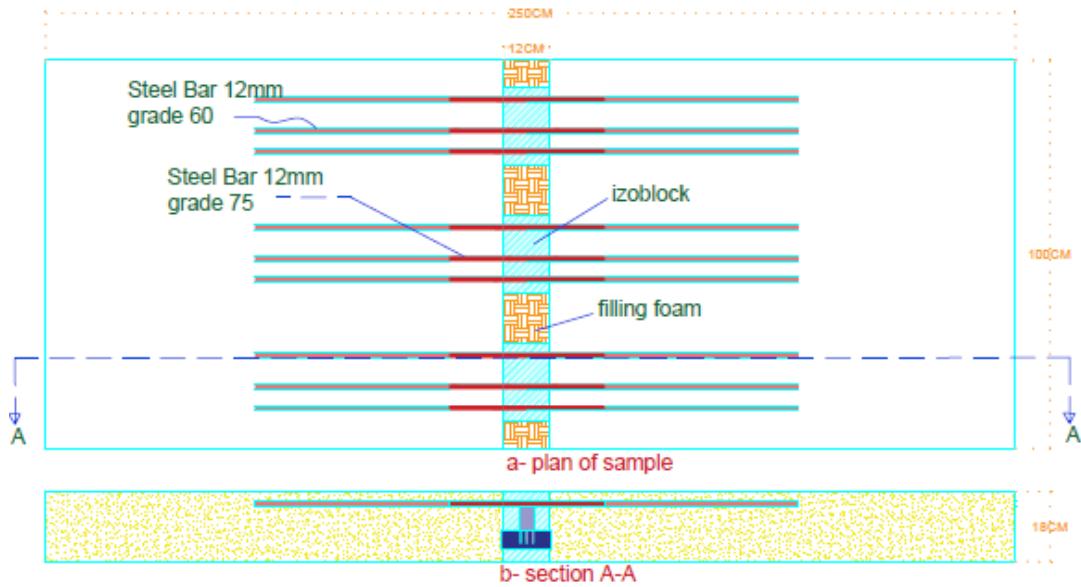


Figure 3.7. Distribution Izoblock in balcony sample.

3.5. Research program

The balcony was simulated in order to show the deformation of balcony through applying static load. Then model results were validated with results that have been gotten from experimental tests. The study was divided into four groups (G1, G2, G3, G4). First group G1, investigated the effect of compressive strength of concrete on load bearing capacity of the balconies. Five models were made for each concrete type as shown in Table-5. In Second group G2, the number of Izoblocks were changed in similar model (two, three and four Izoblocks were used). In third group G3 shape of high strength concrete block inside the Izoblock were changed to three shapes (square, triangle and circular). In last group G4, thickness of steel plates were changed (1mm, 2mm, 3mm).

- G1 → change the compressive strength (35Mpa, 45Mpa, 55Mpa, 65Mpa, 75Mpa)
- G2 → change the number of blocks (2*3blocks, 3*3 blocks, 4*3blocks)
- G3 → change the shape of high strength concrete izoblock (square, triangle, circular)
- G4 → change the thickness of steel plate (1mm, 2mm, 3mm)

Table 3.5. The characteristics of balcony models used in this study

Group Name	No.	Concrete	Number of Block	Concrete Shape	Steel Plate
G1	1	C35			
	2	C45	3(3: square shape)	Square shape w*h = (5*5) cm	W x H x T (5cm * 9cm *2mm)
	3	C55			
	4	C65			
	5	C75			
G2	6	C55	2(3: square shape)	Square shape w*h = (5*5) cm	W x H x T (5cm * 9cm *2mm)
	7		4(3: square shape)		
	8	C55	3(3: square shape)	Triangle shape B*h = (10*5) cm	W x H x T (5cm * 9cm *2mm)
G3	9			Circular shape R=2.82 cm	
	10				W x H x T (5cm * 9cm *1mm)
	11	C55	3(3: square shape)	Square shape w*h = (5*5) cm	W x H x T (5cm * 9cm *2mm)
G4	12				W x H x T (5cm * 9cm *3mm)

3.6. LVDT distributions

Four LVDT's are used to measure the displacement of concrete balcony at specific locations. The tow high-sensitivity LVDT (4&5) are fixed on free end of sample, the LVDT (2&6) fixed on balcony-lintel-walls-floor-thermal break. The LVDTs are fixed on

both ends of balcony and placed carefully on the top of thermal bridge zone as shown in (Figure 3.8).

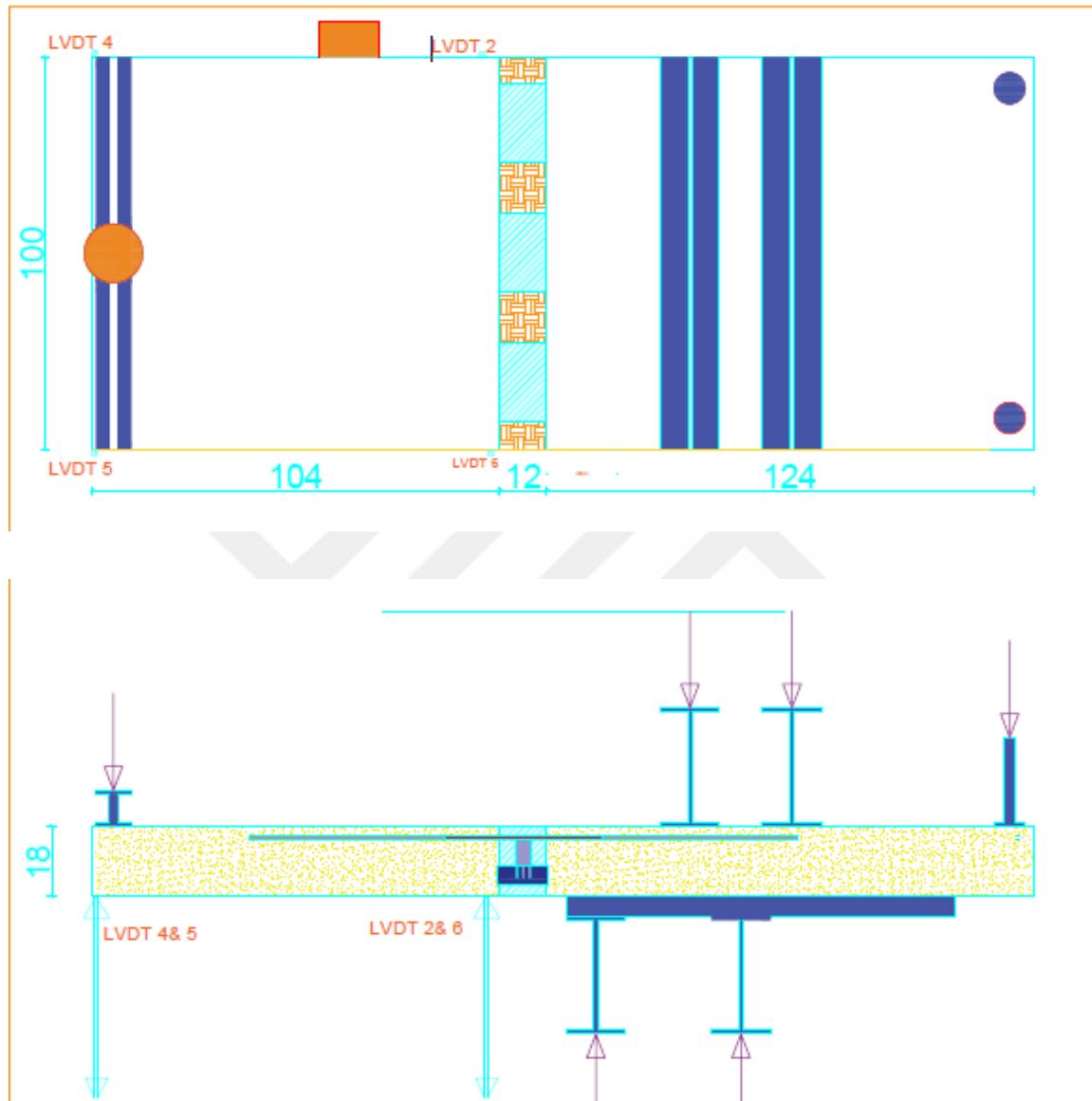


Figure 3.8. Diagrams and location of LVDT's in the balcony.

3.7. Effect of Concrete Strength, Size, Shape and Number of Blocks Inside the IzoBlocks on Load Capacity of Balconies

3.7.1. Effect of IzoBlock compressive strength on balcony

As it's mentioned before, in first model (G1) compressive strength has been changed and it leads to provide several results as discussed below. In addition, several different comparative strengths were added in the model including C35, C45, C55, C65 and C75 with having full details such as; sample sizes, maximum compressive strength for the static and dynamic loading tests with different strain rates. Five grades of concretes with static uniaxial compressive strengths of ~ 35 MPa, ~ 45 MPa ~ 55 MPa ~ 65 MPa and ~ 75 MPa are denoted as C35, C45, C55, C65 and C75, respectively.

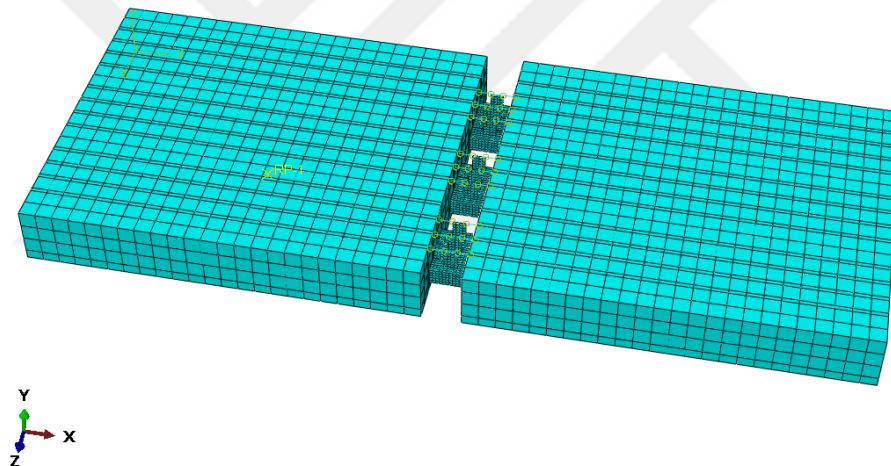


Figure 3.9. Reinforced concrete balcony slab model developed using Abaqus Software in vertical shape.

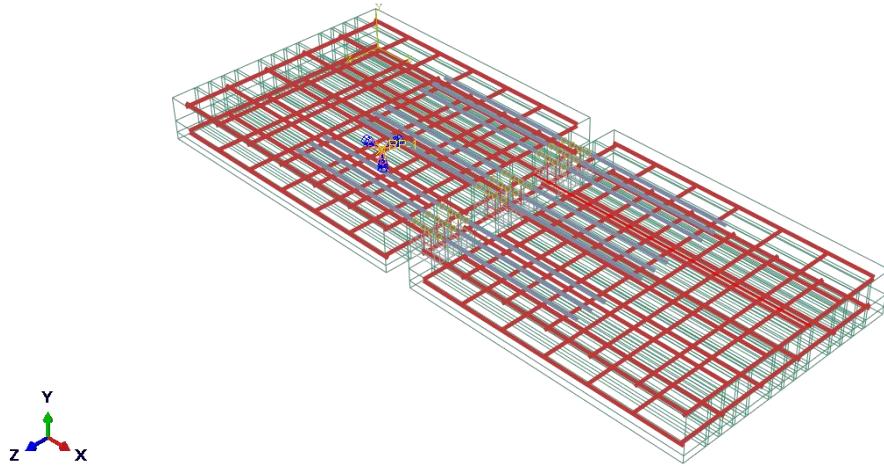


Figure 3.10. 3D sample of Reinforced concrete balcony slab structure in Abaqus software.

3.7.2. Influence of number of IzоБlock on edge displacement

As it's known, three different IzоБlock has been used in the sample (sample one has 3 IzоБlock, sample two has 4 IzоБlock, and sample three has 2 IzоБlock), while in this part the number of IzоБlocks has been changed, in which one block is added to sample one (became 4 Izoblock) and then one IzоБlock removed from sample 3 (became 2 Izoblock) as shown in (figure 3.12&3.13).

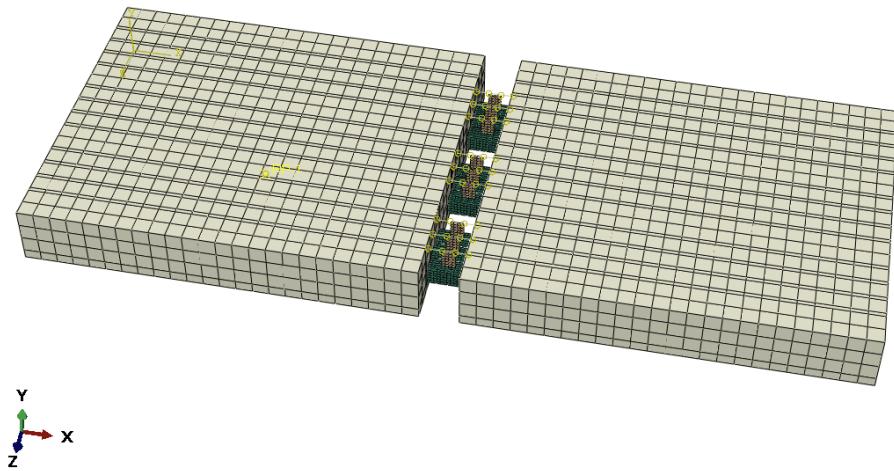


Figure 3.11. Sample one with containing three IzоБlock.

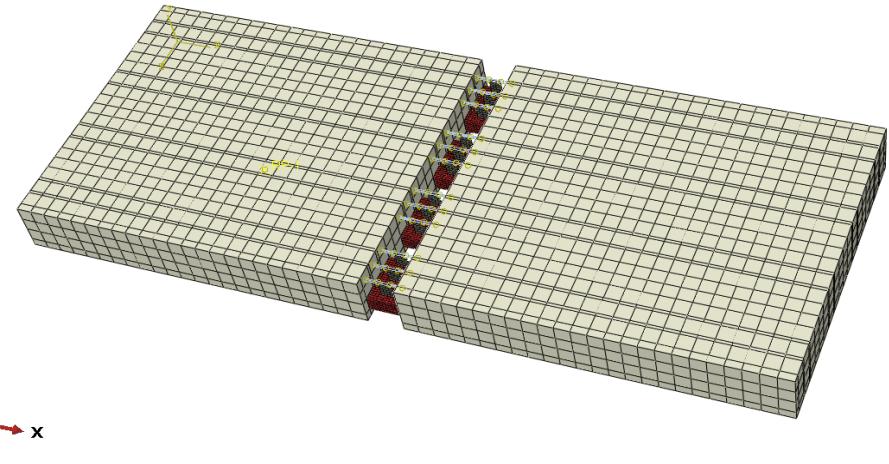


Figure 3.12. Sample two containing four IzoBlocks.

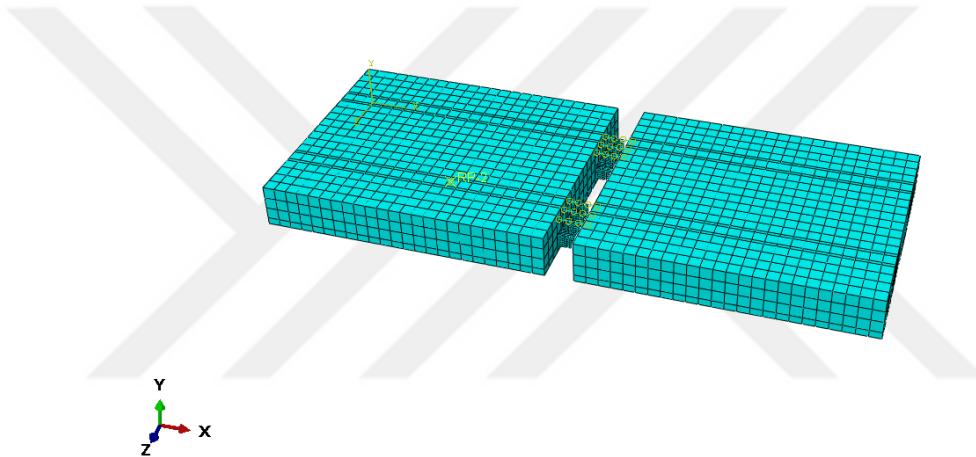


Figure 3.13. Sample three containing two IzoBlocks

3.7.3. Influence of concrete block shapes on edge displacement

To evaluate the reliability of the model presented in this study, numerical simulations have been utilized. The experiments including the bending tests of high-strength concrete known as C55, having a shape 50mm*50mm (square and 120 mm height) were implemented as shown in (Figure 3.14). In this section, the shape of the block has been changed to triangular shape (Base= 10 cm- height= 5cm) and circular shape ($R= 2.82$ cm). In addition, the section area of triangular and circular shape was the same as square section area shown in (Figure 3.15&3.16), the bending strength and maximum compressive strength are commuting with the experiment sample are given in Table 3&4 in Section 2.

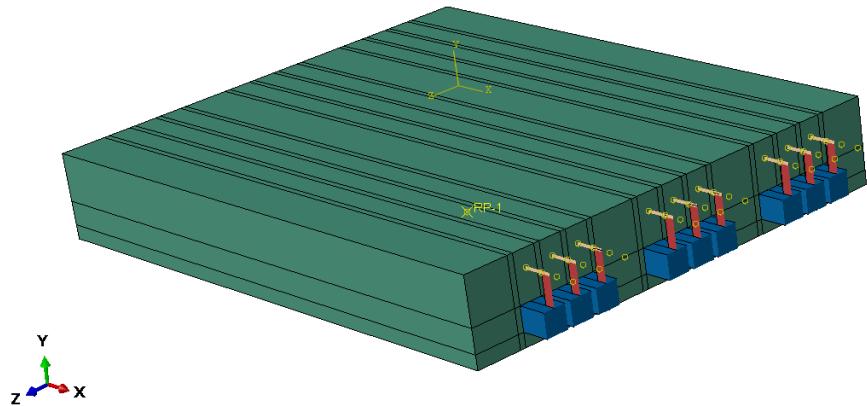


Figure 3.14. Square block shape.

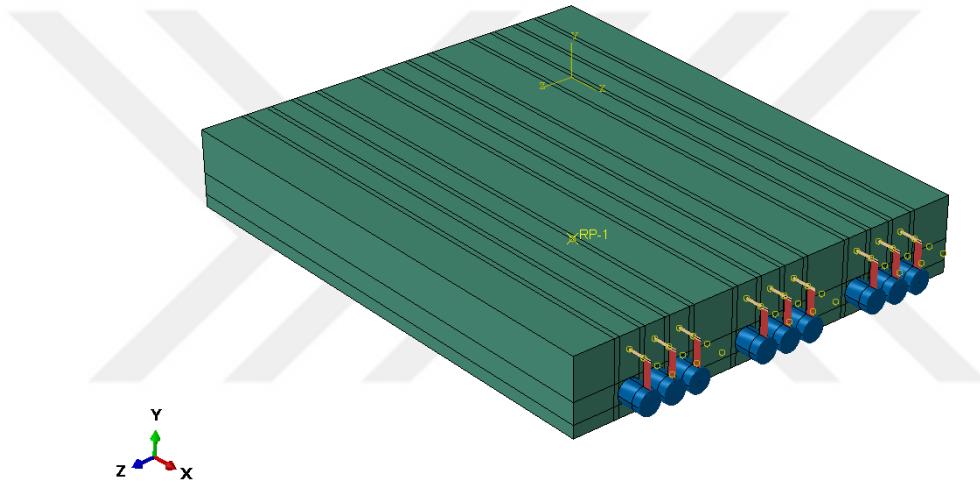


Figure 3.15. Circular block shape.

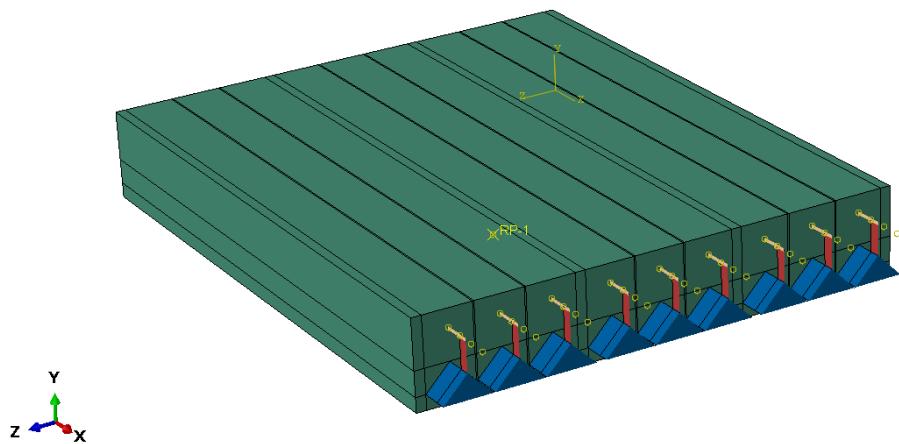


Figure 3.16. Triangular block shape.

3.1.4. Effect of thickness of shear plate on edge displacement

For the numerical FE code, Abaqus 2019 and its explicit solver Abaqus/Explicit was used. Steel plate (shear plate), the size of plate used in experiments is 40mm wide, 90mm high and 2mm thick. In this study, the thickness of shear plate in simulation were changed by 1mm and 3mm, as shown in Figure (3.17). During the simulation of test, numerical instability problems were experienced because of the relatively sever damage. Therefore, the automatic conversion of finite elements to mesh-free particles which is called “Smoothed Particle Hydrodynamics (SPH)” method was applied to deal with this problem. In this study, only standard material models incorporated in Abaqus were used.

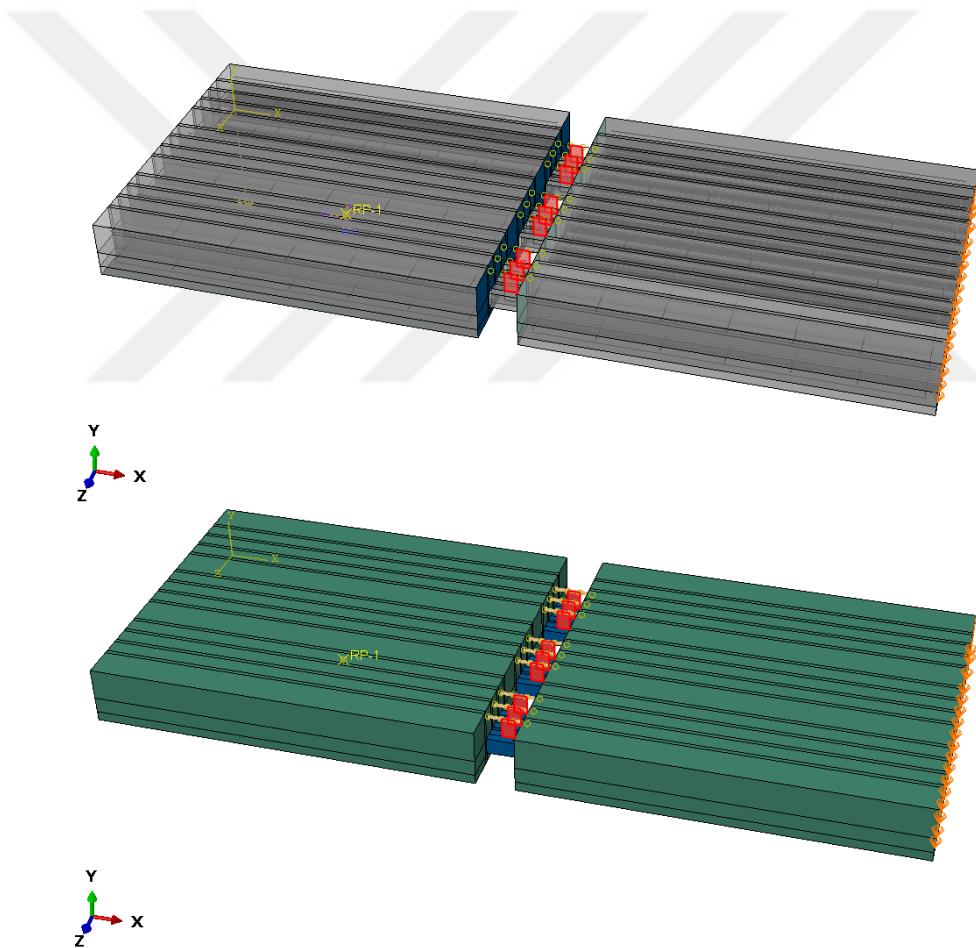


Figure 3.17. Shear plate simulations using Abaqus software.



4. RESULTS AND DISCUSSION

In this study, experimental and computational techniques are used to simulate the bending strength of a balcony slab constructed with thermal break elements named as IzoBlock. The experimental work is made at laboratory of Inovan Yapı Teknik Sanayi ve Ticaret Ltd. Şti. In addition, the properties of foam, steel, and other elements were given in Chapter 3. The strength of foam was less therefore, foam was ignored and structural element as well as the conductivity was not investigated in this study, and steel have been added to the concrete to provide homogeneity. So, well bond strength combined with the concrete in the balcony slab construction. 12 concrete balcony slab structures have been simulated in order to determine the effect of different parameters on load bearing capacity of balconies. This chapter discusses the results of evaluating the structure's strength and displacement with bending testing equipment.

Bending test have been applied on four groups or categories thermal bricking balcony slabs. The result of the tests are shown in Tables 4.1, 4.2, and 4.3 in appendix A.

4.1. Load-Bearing Capacity of Ordinary Reinforced Concrete Balcony

Abaqus software has been used to create the model for normal concrete balcony. Displacement is plotted in Figure 4.1. Fig. 4.1 shows the results of the test, which are represented by distinct lines and colors. Within the balcony slab construction, each sensor is moved to a certain point. This sensor indicates the largest displacement shift when greater load is applied. When 56.18 KN of load is given to sensor LVDT-5, it displays a displacement of 32.56 mm, whereas sensor LVDT-4 shows a displacement of 34.03 mm, and LVDT-2 shows a displacement of 2.76mm when 56.18 KN of weight is applied. Figure 4.2 shows. In the case of LVDT-6, which is shown in green, a load of 56.18 KN resulted in a displacement of 2.76 mm.

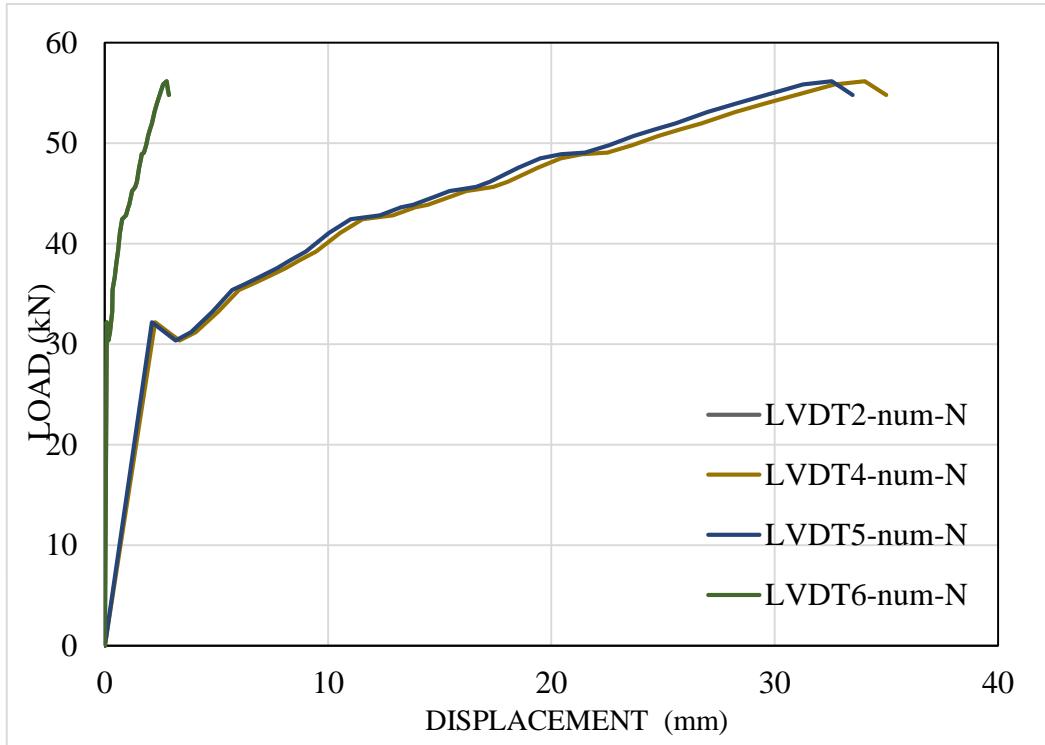


Figure 4.1. Bending test for the normal balcony slab concrete structure.

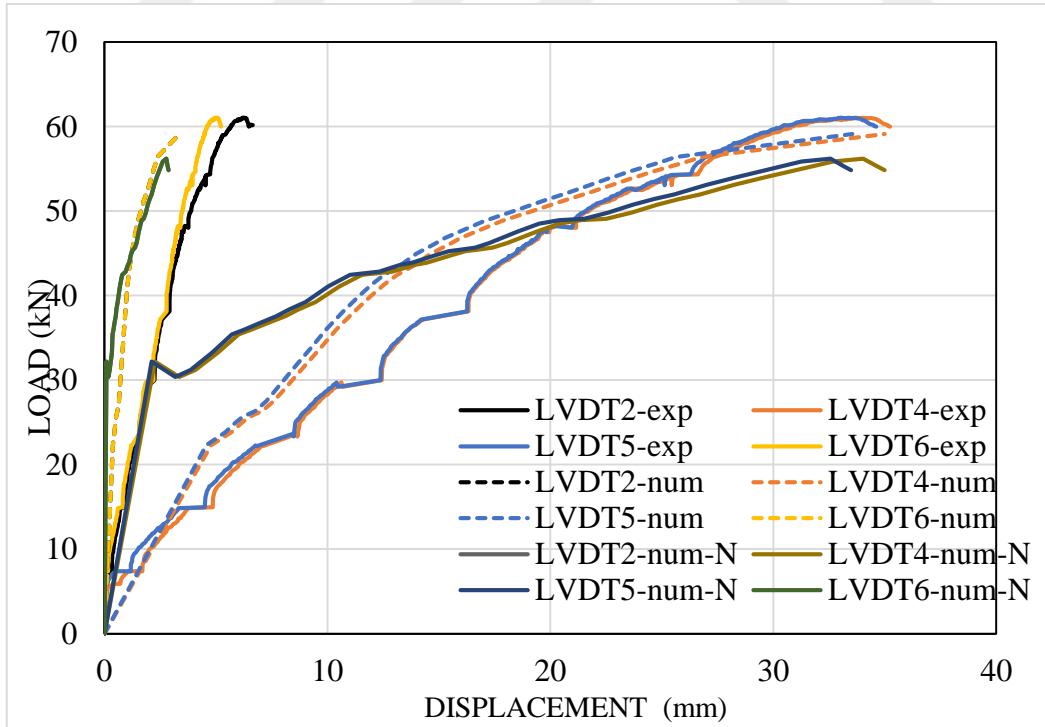


Figure 4.2. Comparison of bending test results of ordinary balcony and balcony with IzoBlock (experimental and numerical results).

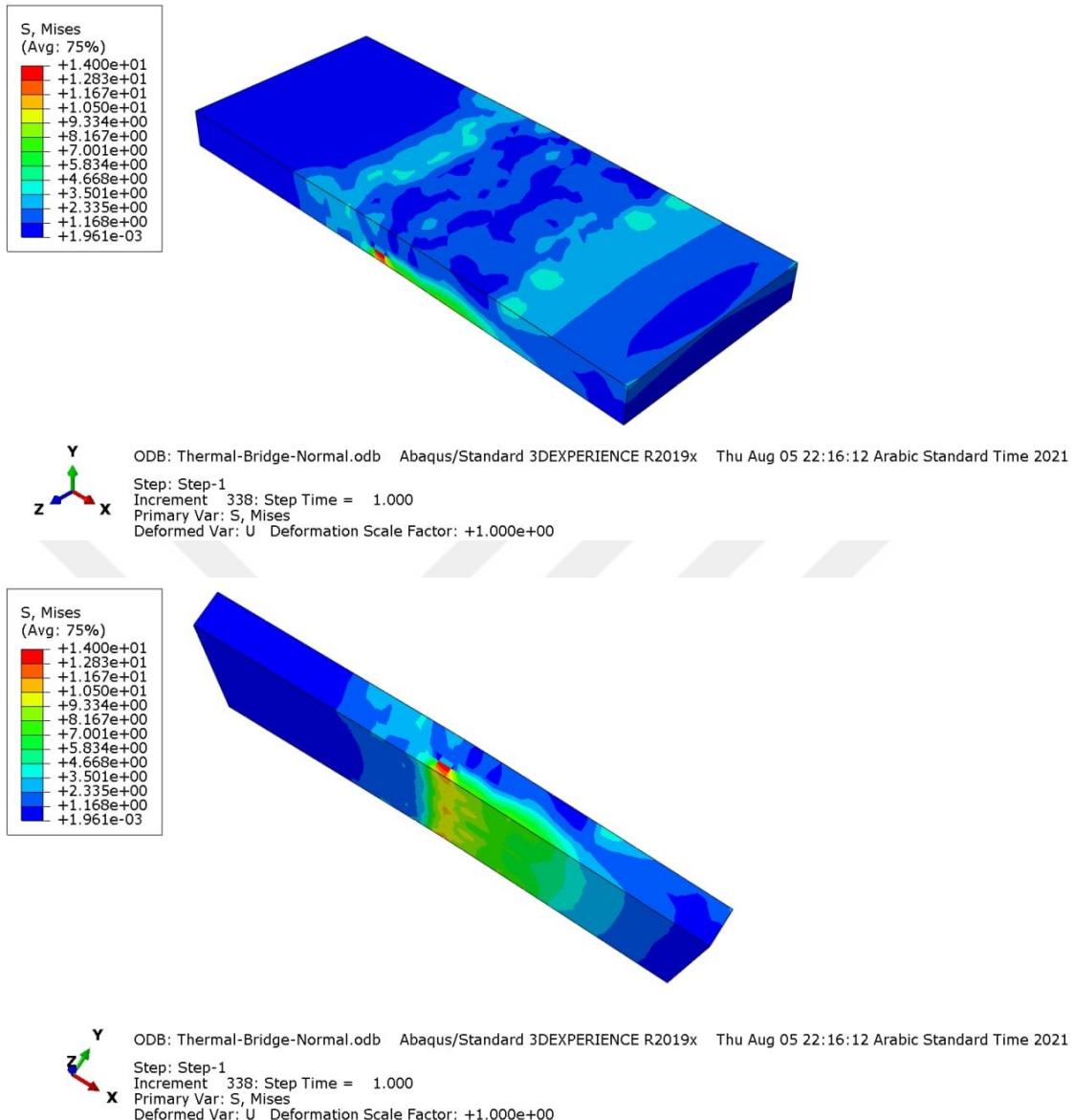


Figure 4.3. Model of the normal concrete balcony slab structure.

4.2. Load-Bearing Capacity of Reinforced Concrete Balcony with IzoBlocks

Bending load capacity of the balconies with IzoBlocks has been evaluated by several researchers, so, the data of one of the thesis is plotted in Figure 4.4 (Bikhtiyar's Thesis). This figure shows the results of the test, which are represented by distinct lines and colors. Within the balcony slab construction, each sensor is moved to a certain point. This sensor indicates the largest displacement shift when greater loads are applied. When 60.01 KN of load is given to sensor LVDT-5, it displays a displacement of 30.38 mm, whereas sensor LVDT-4 shows a displacement of 30.9 mm, and LVDT-2 shows a

displacement of 5.65 mm when 60KN of weight is applied. Figure 4.4 shows. In the case of LVDT-6, which is shown in green, a load of 60 KN resulted in a displacement of 4.61 mm.

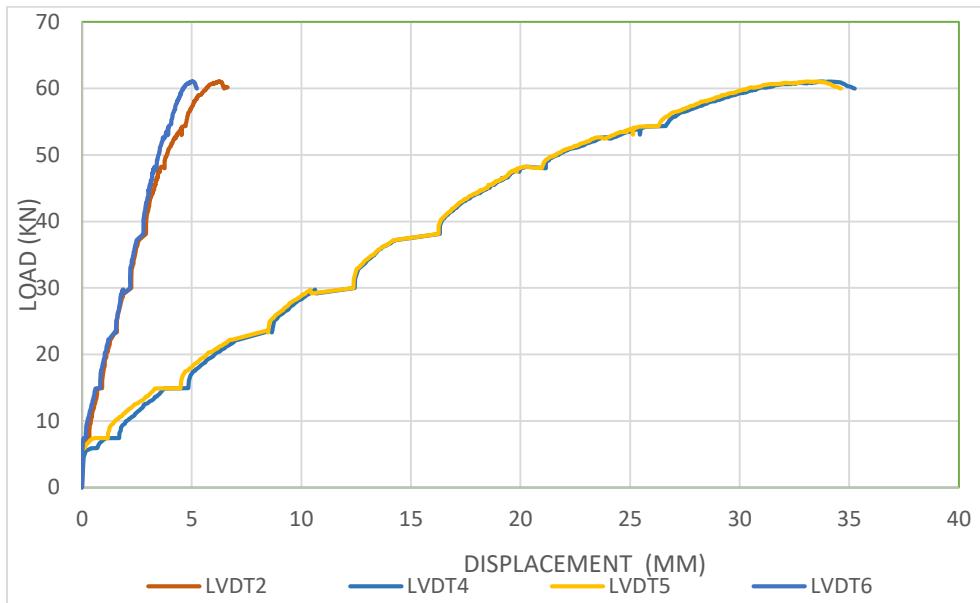


Figure 4.4. Bending test result of balcony with IzoBlock.

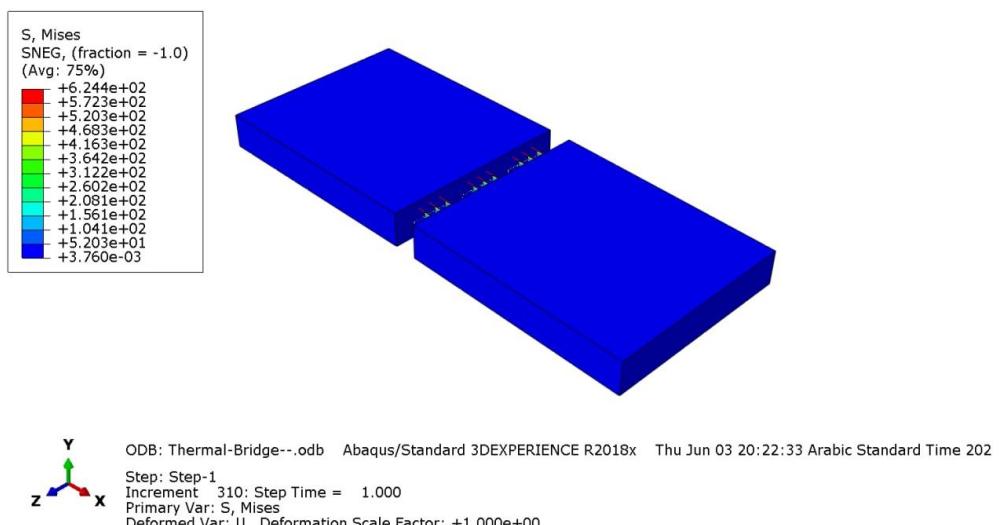


Figure 4.5. Model Bending test for the experimental Model balcony slab concrete structure

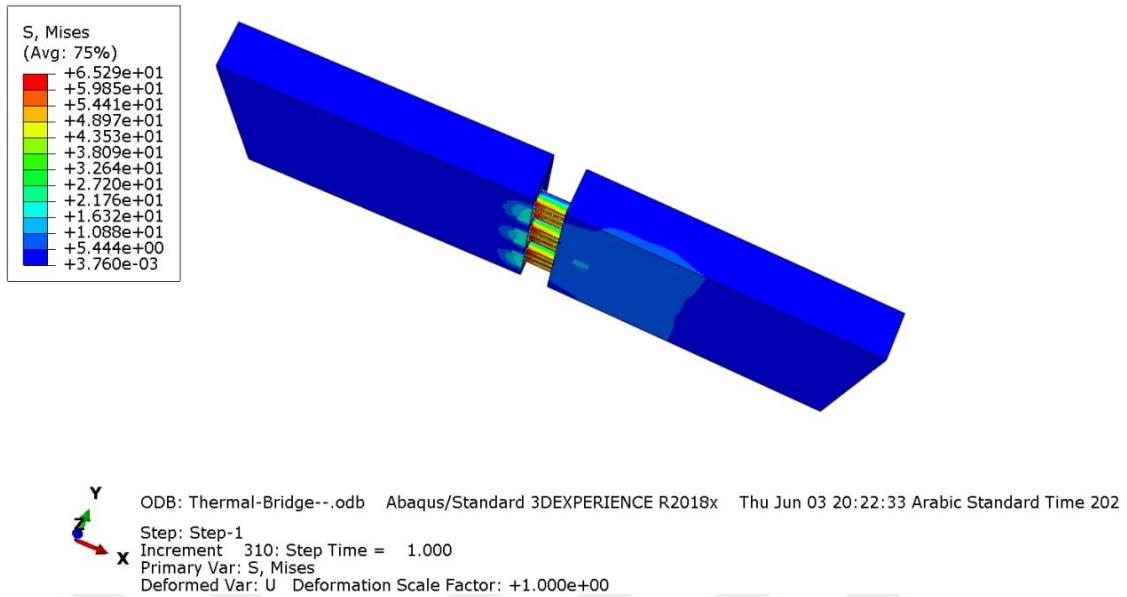


Figure 4.6. Model Bending test for the experimental Model balcony slab concrete structure (continued).

4.3. Effect of Compressive Strength of Izoblocks on Load-Bearing Capacity of Balconies with Izoblocks

4.4. The Effect of Compressive Strength of Izoblocks on the Bending Load Capacity of Reinforced Concrete Slabs Are Investigated and the Results Are Given Below.

4.4.1. Load-displacement behavior of balcony with IzoBlock having a compressive strength of 35 Mpa

The balcony sample with IzoBlock having 35 MPa compressive strength reached its ultimate capacity at 47.7 kN load after applying 60.01 kN on it. Also, 19.7 mm of displacement noted through using sensor LVDT-5-num and LVDT-4-num in simulation software Abaqus. And, 1.85 mm of displacement has been detected by LVDT-6-num and LVDT-2 which is shown as hidden line in (Figure 4.6). Also, through comparing the simulation results with experimental results, the data were quite different, because compressive strength in experimental test was 55 Mpa, and the result of sensor LVDT-exp (2,4,5and 6) was (5.65 mm, 30.9mm, 30.38 mm and 4.61mm) respectively, as shown in Figure 4.6 with full line.

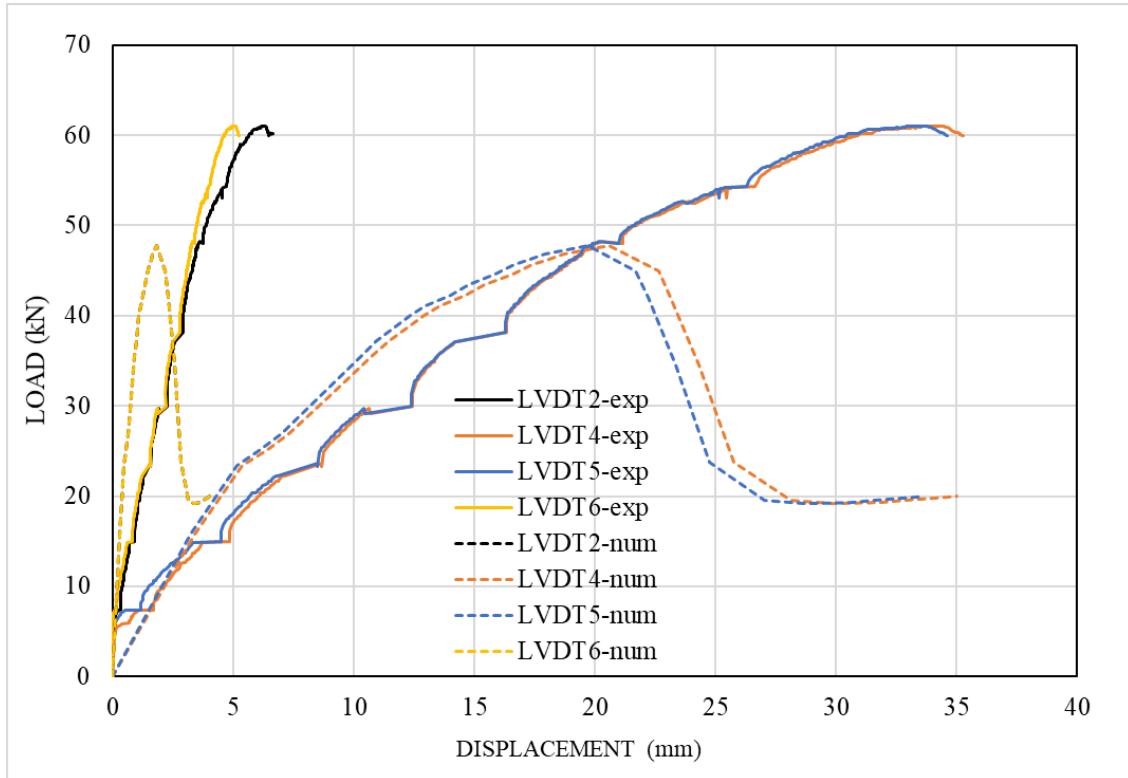


Figure 4.7. Bending capacity of the balcony model for the case of IzoBlock with 35Mpa compressive strength.

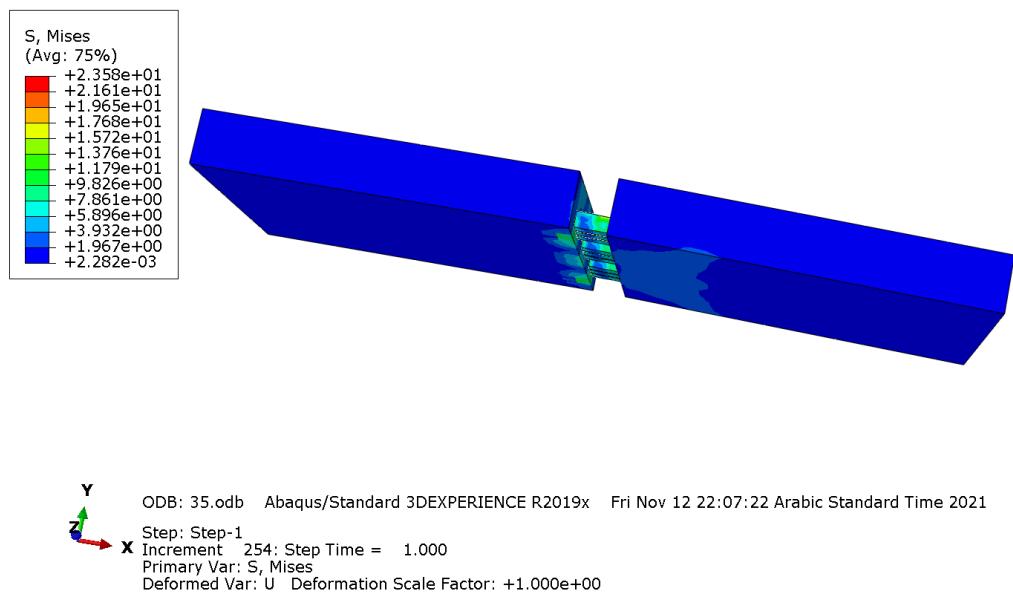


Figure 4.8. Model of the balcony using IzoBlock with 35Mpa concrete compressive strength.

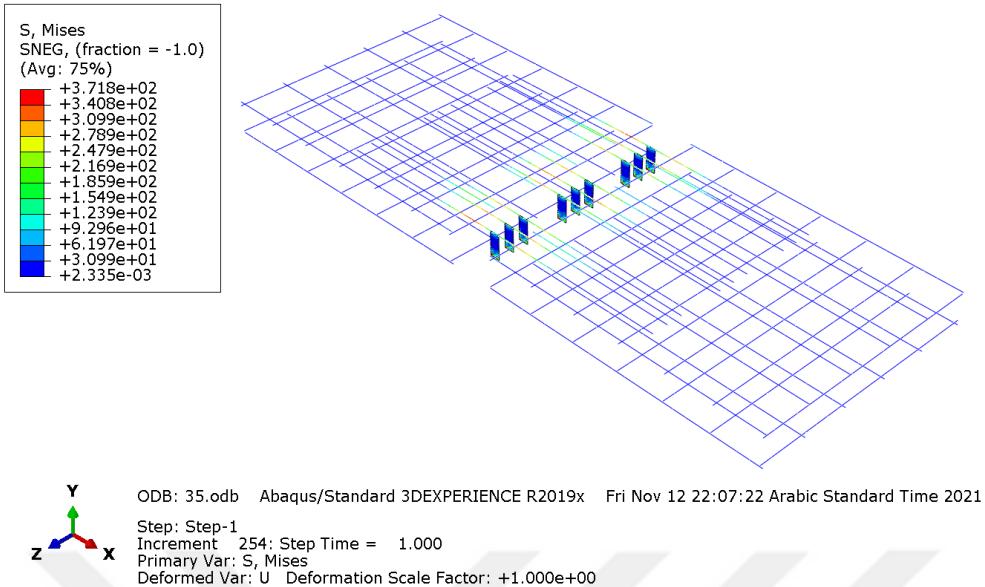


Figure 4.9. Model of the balcony using IzoBlock with 35Mpa concrete compressive strength (continued).

4.4.2. Load-displacement behavior of balcony with IzoBlock having a compressive strength of 45 Mpa

The balcony having IzoBlock with a concrete compressive strength of 45 MPa was broken in 56.03 kN after applying 60.01 kN on it. Also, 28.75 mm of displacement noted through using sensor LVDT-5-num and 30.01 mm LVDT-4-num in simulation software Abaqus. And, 2.69 mm of displacement has been detected by LVDT-6-num and LVDT-2 which is shown as hidden line in 4.8. Also, through comparing the simulation results with experimental results, the data were quite different, because compressive strength in experimental sample was 55 Mpa, and the result of sensor LVDT-exp (2,4,5and 6) was (5.65 mm, 30.9mm, 30.38 mm and 4.61mm) respectively, as shown in (Figure 4.8).

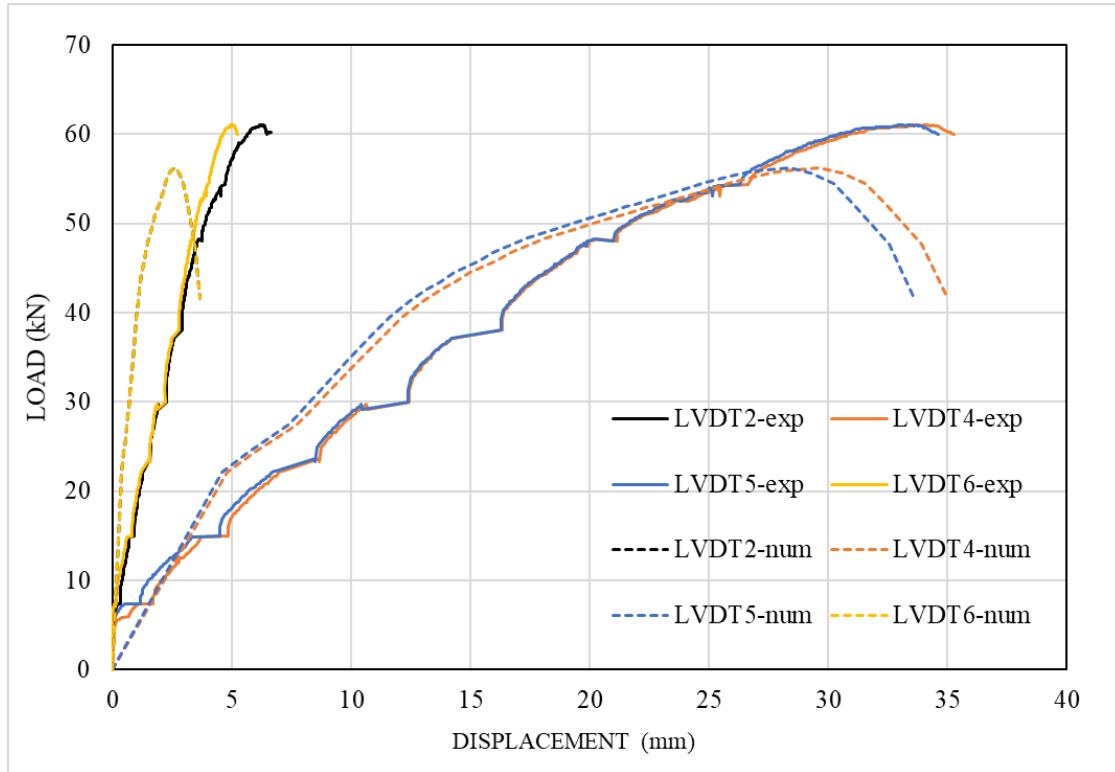


Figure 4.10. Bending capacity of the balcony model for the case of IzoBlock with 45Mpa compressive strength.

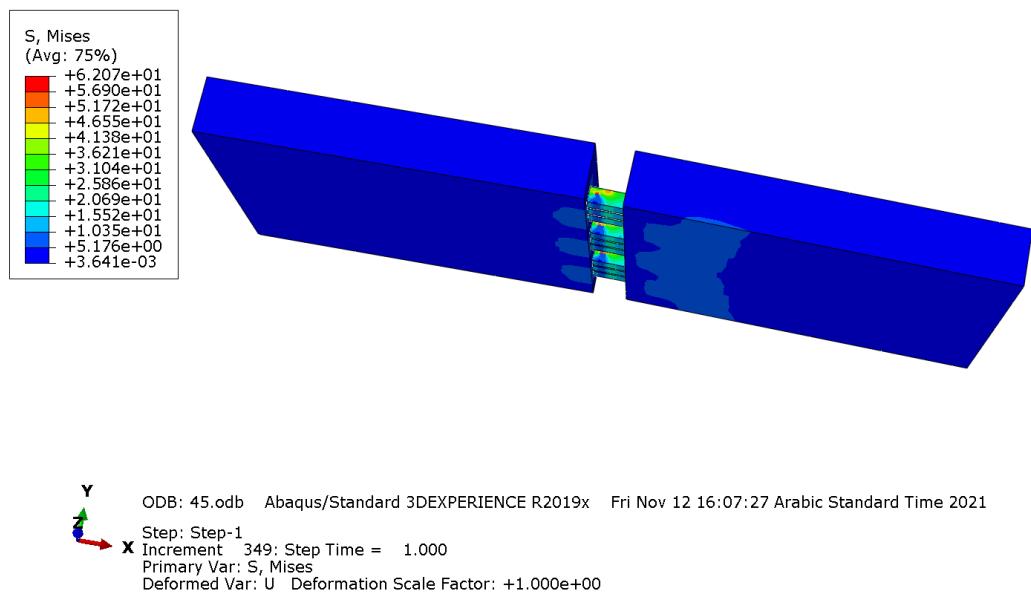


Figure 4.11. Model of the balcony using IzoBlock with 45Mpa concrete compressive strength.

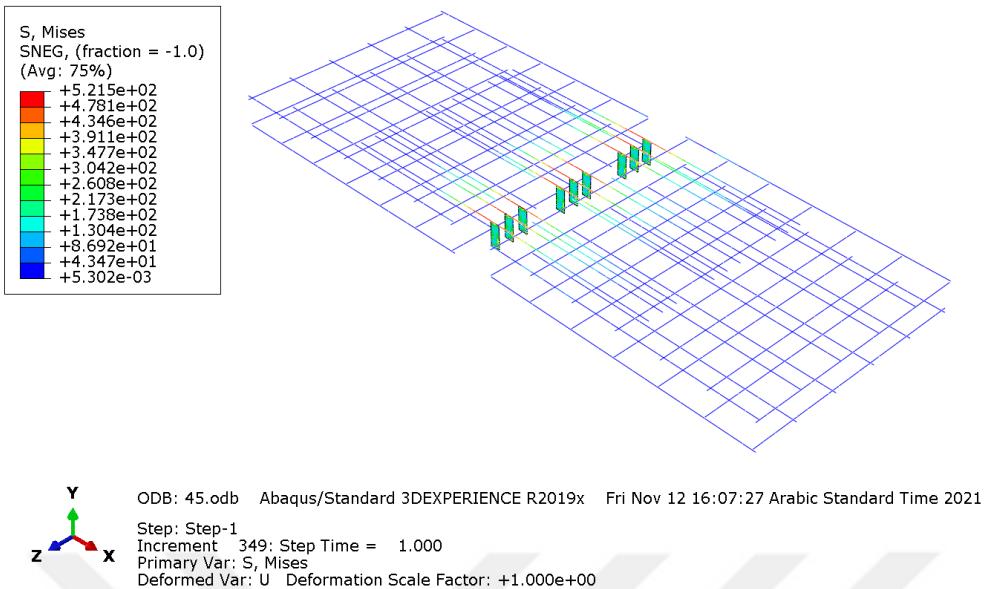


Figure 4.12. Model of the balcony using IzoBlock with 45Mpa concrete compressive strength (continued).

4.4.3. Load-displacement behavior of balcony with IzoBlock having a compressive strength of 55 Mpa

The balcony having IzoBlock with a concrete compressive strength of 55 MPa was broken in 58.86 kN after applying 60.01 kN on it. Also, 33.54 mm of displacement noted through using sensor LVDT-5-num and 35 mm LVDT-4-num in simulation software Abaqus. And, 3.27 mm of displacement has been detected by LVDT-6-num and LVDT-2 which is shown as hidden line in 4.10. Also, through comparing the simulation results with experimental results, the data were quite different, because compressive strength in experimental sample was 55 Mpa, and the result of sensor LVDT-exp (2,4,5and 6) was (5.65 mm, 30.9mm, 30.38 mm and 4.61mm) respectively, as shown in (Figure 4.10).

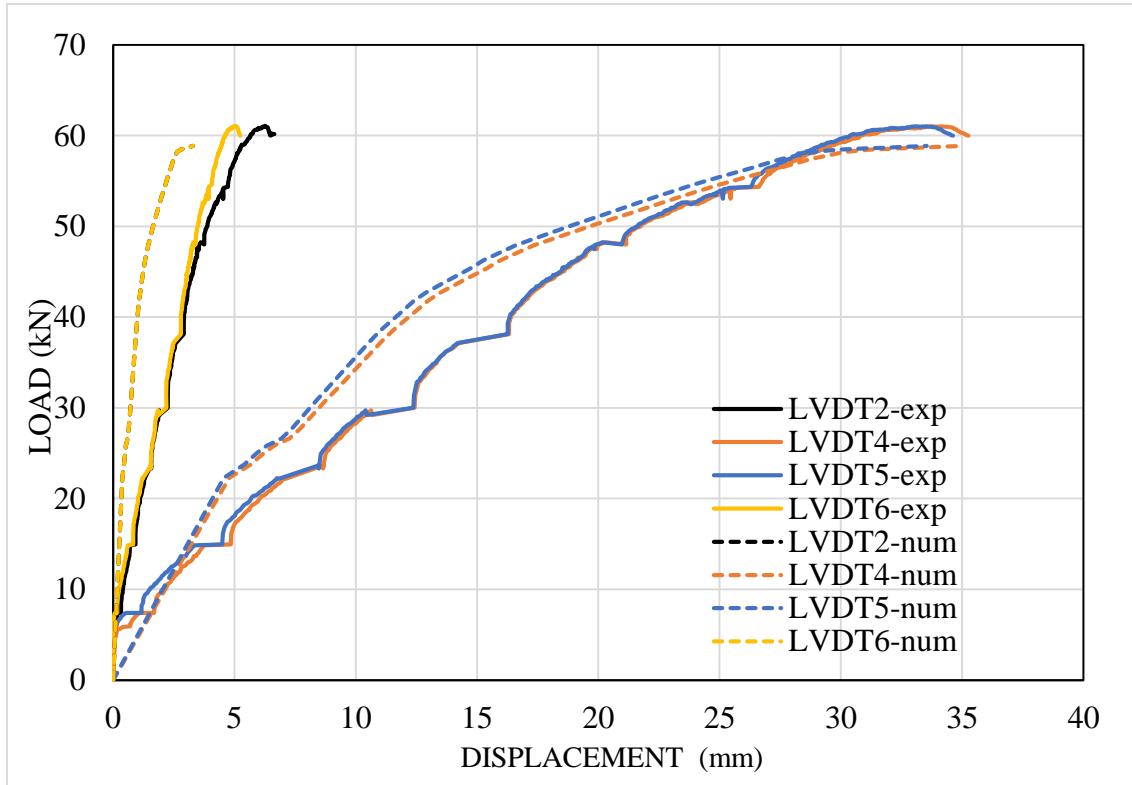


Figure 4.13. Bending capacity of the balcony model for the case of IzoBlock with 55Mpa compressive strength.

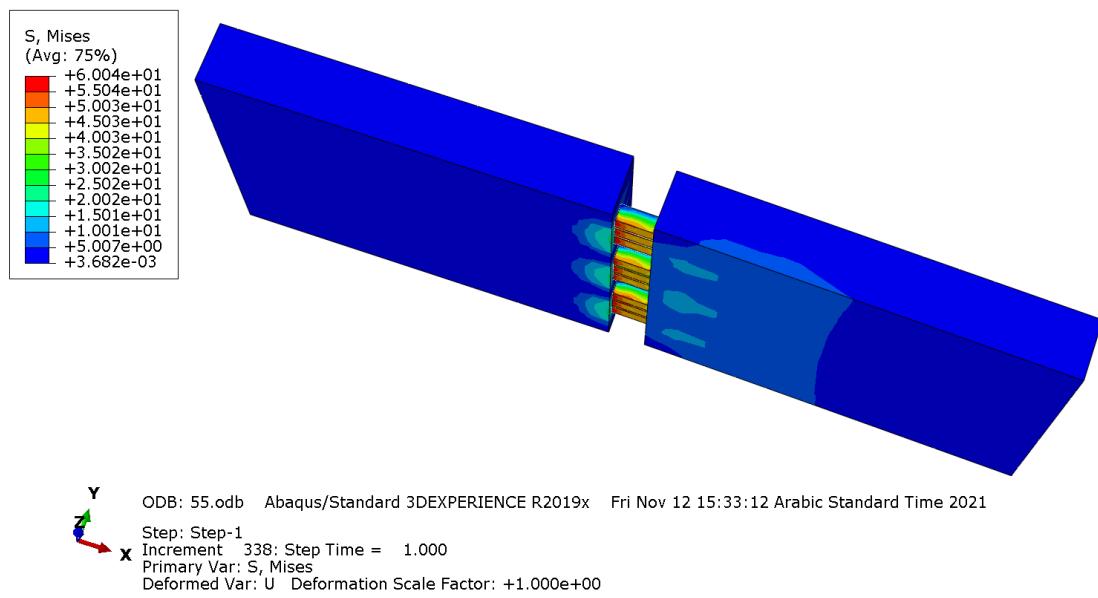


Figure 4.14. Model of the balcony using IzoBlock with 55Mpa concrete compressive strength.

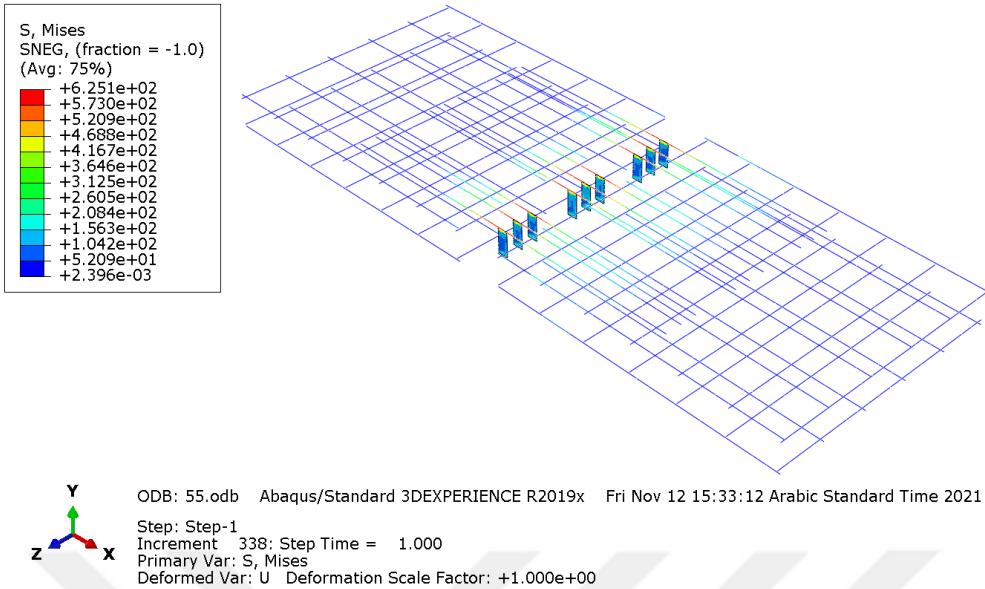


Figure 4.15. Model of the balcony using IzoBlock with 55Mpa concrete compressive strength (continued).

4.4.4. Load-displacement behavior of balcony with Izoblock having a compressive strength of 65 Mpa

The balcony having IzoBlock with a concrete compressive strength of 65 MPa was broken in 58.99 kN after applying 60.01 kN on it. Also, 33.54 mm of displacement noted through using sensor LVDT-5-num and 35 mm LVDT-4-num in simulation software Abaqus. And, 3.31 mm of displacement has been detected by LVDT-6-num and LVDT-2 which is shown as hidden line in 4.12. Also, through comparing the simulation results with experimental results, the data were quite different, because compressive strength in experimental sample was 55Mpa, and the result of sensor LVDT-exp (2,4,5and 6) was (5.65 mm, 30.9mm, 30.38 mm and 4.61mm) respectively, as shown in Figure 4.12.

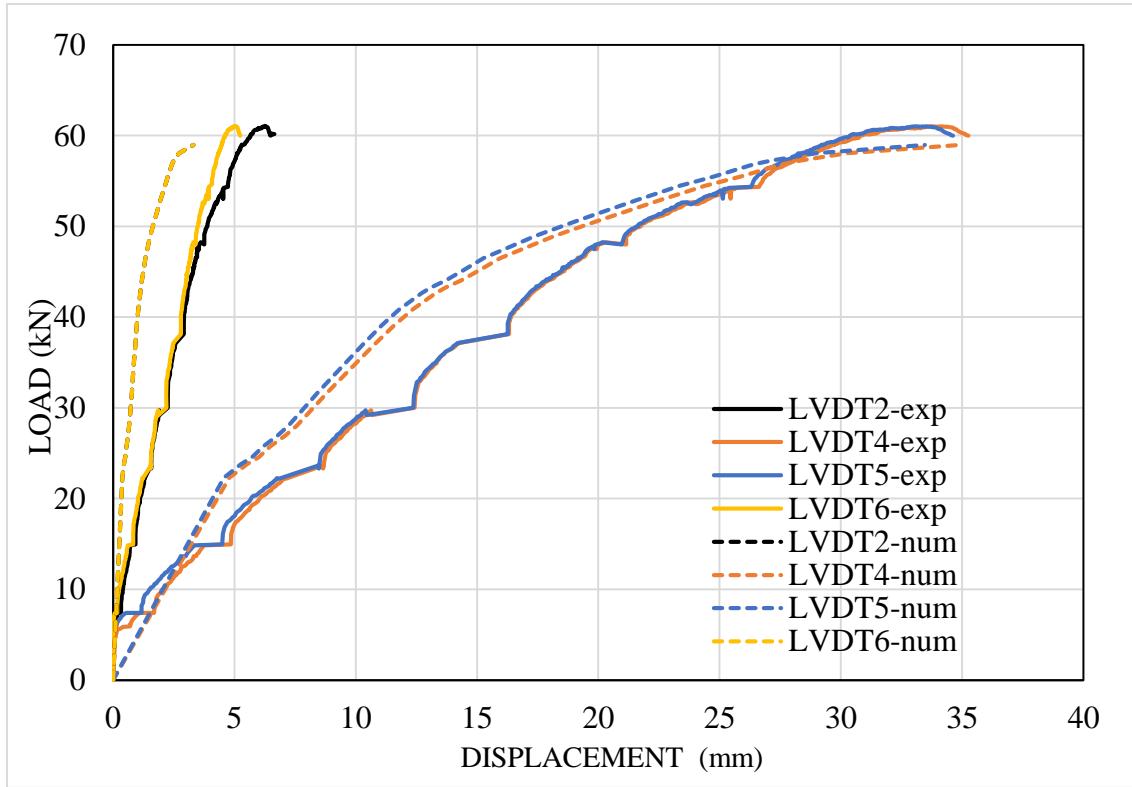


Figure 4.16. Bending capacity of the balcony model for the case of IzoBlock with 65Mpa compressive strength.

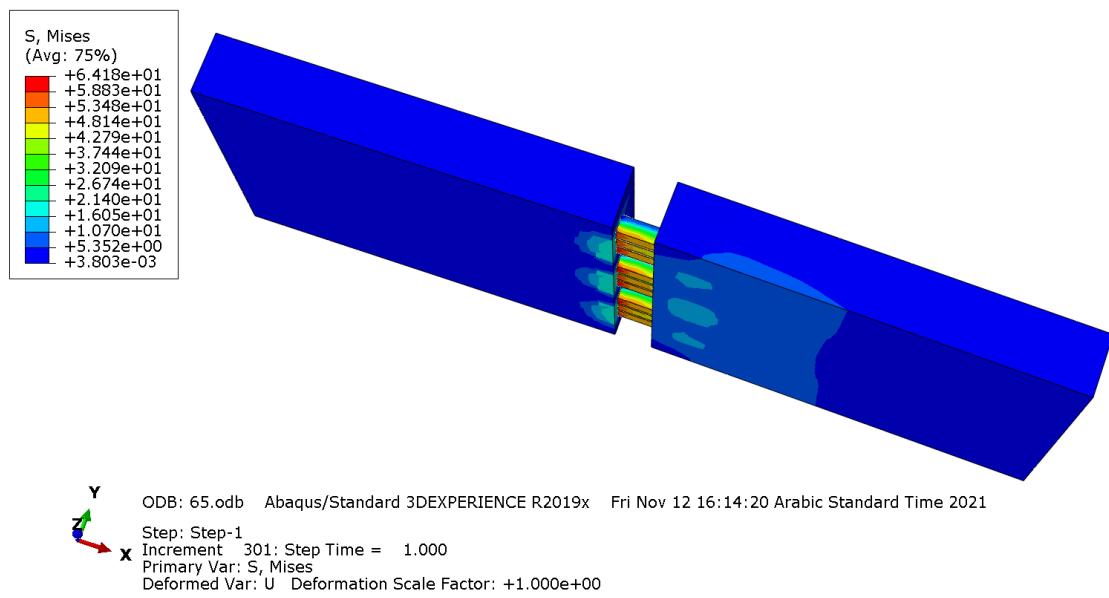


Figure 4.17. Model of the balcony using IzoBlock with 65Mpa concrete compressive strength.

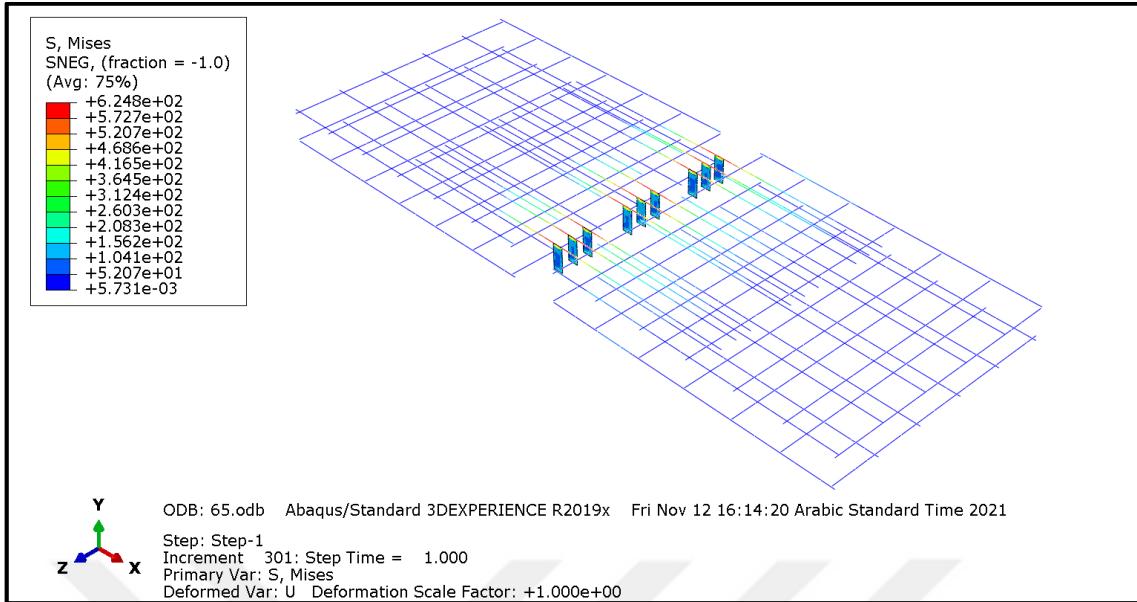


Figure 4.18. Model of the balcony using Izoblock with 65Mpa concrete compressive strength (continued).

4.4.5. Load-displacement behavior of balcony with Izoblock having a compressive strength of 75 Mpa

The balcony having Izoblock with a concrete compressive strength of 75 MPa was broken in 59.97 kN after applying 60.01 kN on it. Also, 33.54 mm of displacement noted through using sensor LVDT-5-num and 35 mm LVDT-4-num in simulation software Abaqus. And, 3.33 mm of displacement has been detected by LVDT-6-num and LVDT-2 which is shown as hidden line in (Figure 4.14). Also, through comparing the simulation results with experimental results, the data were quite different, because compressive strength in experimental sample was 55Mpa, and the result of sensor LVDT-exp (2,4,5 and 6) was (5.65 mm, 30.9mm, 30.38 mm and 4.61mm) respectively, as shown in (Figure 4.14).

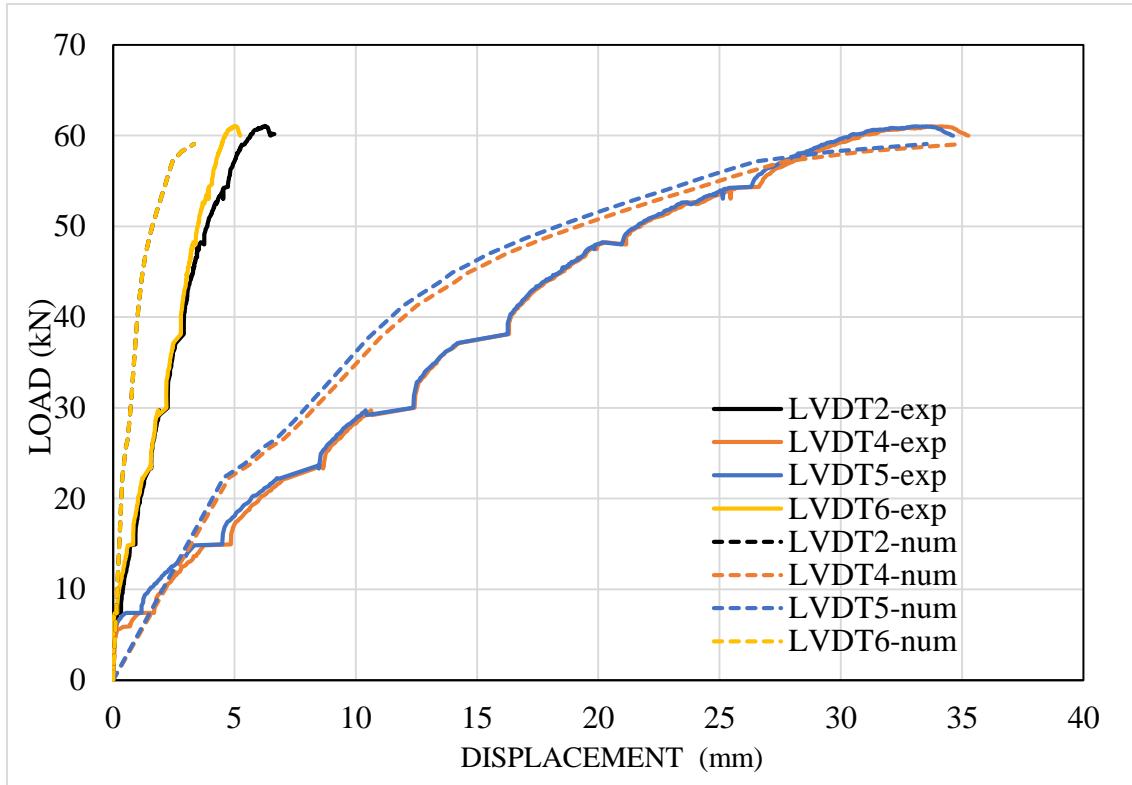


Figure 4.19. Bending capacity of the balcony model for the case of IzoBlock with 75Mpa compressive strength.

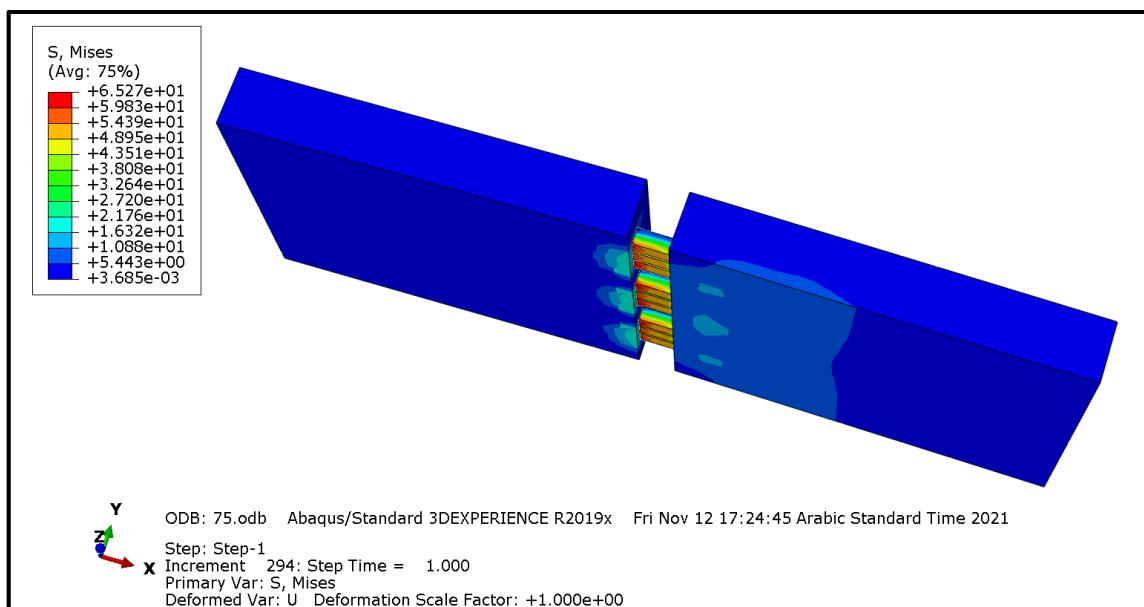


Figure 4.20. Model of the balcony using IzoBlock with 75Mpa concrete compressive strength.

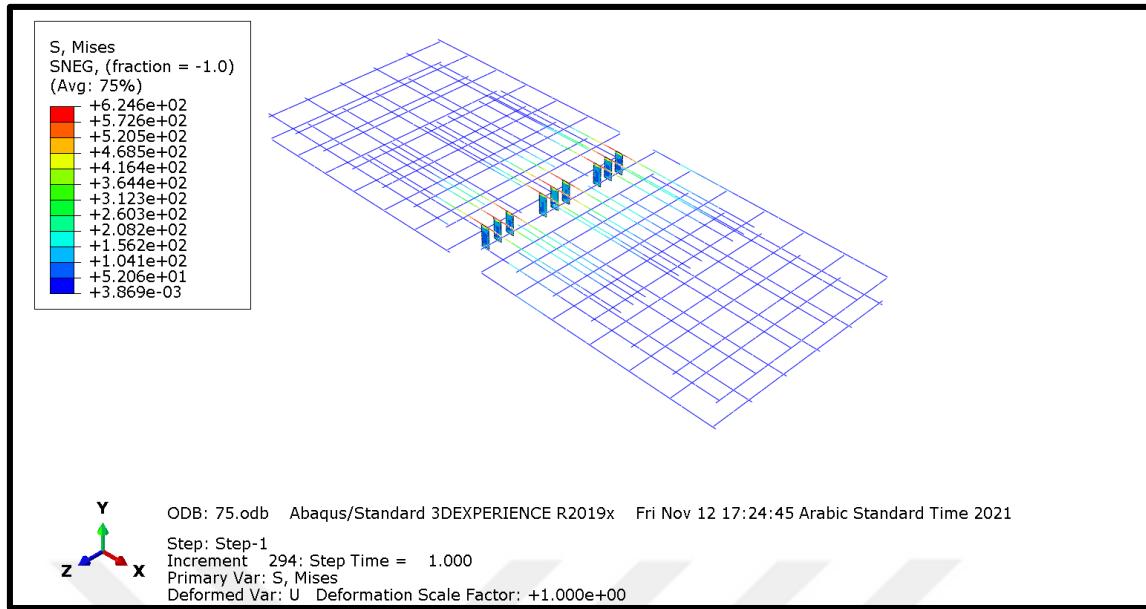


Figure 4.21. Model of the balcony using IzoBlock with 75Mpa concrete compressive strength (continued).

Table 4.1. Comparison of the bending test results (ultimate capacity) of experimental tests and numerical models

compressive strength (Mpa)	Applied loading (kn)	Displacement (mm)							
		LVDT2		LVDT4		LVDT5		LVDT6	
		Num.	Exp.	Num.	Exp.	Num.	Exp.	Num.	Exp.
35	47.7	1.85	----	19.7	----	19.7	----	1.85	----
45	56.03	2.96	----	30.01	----	28.75	----	2.68	----
55	58.86	3.27	5.65	35	30.9	33.54	30.38	3.27	4.61
65	58.99	3.31	----	35	----	33.54	----	3.31	----
75	59.97	3.33	----	35	----	33.54	----	3.33	----

4.4.6. Effect of number of IzoBlocks on load bearing capacity of balconies

4.4.6.1. Load-displacement behavior of balcony with two IzoBlocks

As it's discussed before, in the case where two number of IzoBlocks per meter were used in the balcony, the ultimate load was found to be 41.99 kN kN. Also, several results were collected such as, sensor LVDT-5-num displays a displacement of 33.58 mm,

whereas sensor LVDT-4-num shows a displacement of 35 mm, and LVDT-2 shows a displacement of 3.59 mm as shown in (Figure 4.16).

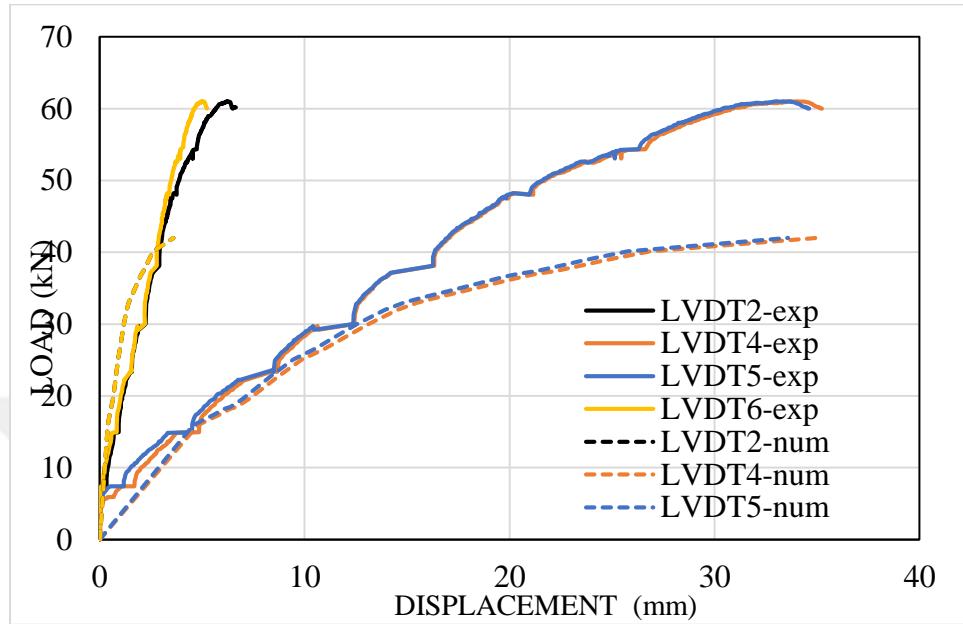


Figure 4.22. Load-displacement behavior of balconies with two IzoBlocks used per meter.

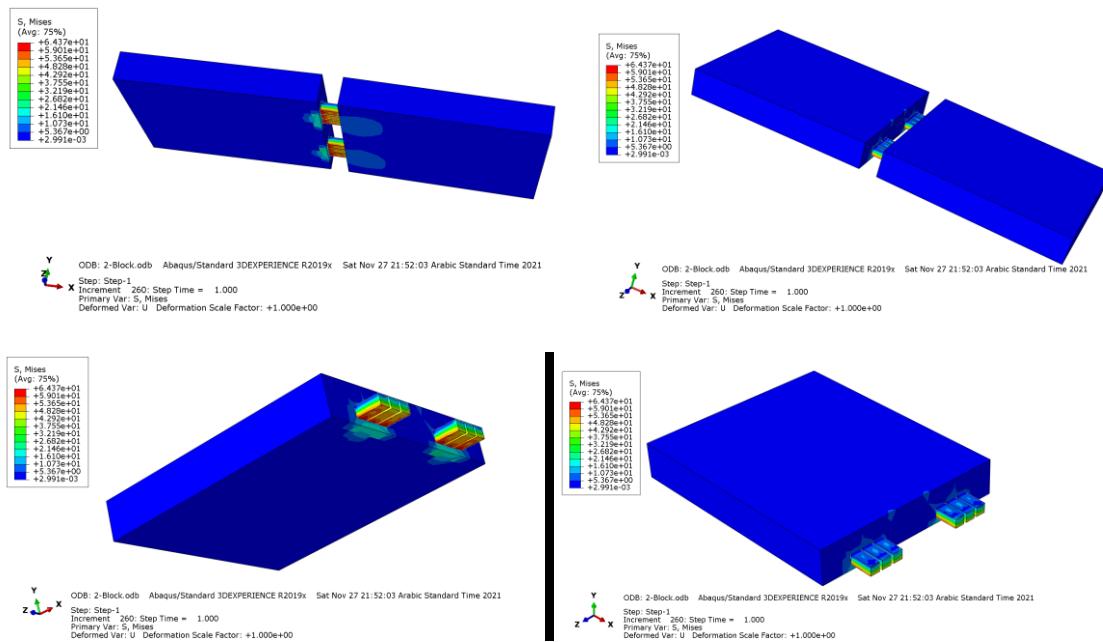


Figure 4.23. Model of the balcony with two IzoBlocks.

4.4.6.2. Load-displacement behavior of balcony with three IzoBlocks

In the case where three number of IzoBlocks per meter were used in the balcony, the ultimate load was found to be 59.1 kN. Also, several results were collected such as, sensor LVDT-5-num displays a displacement of 33.54 mm, whereas sensor LVDT-4-num shows a displacement of 35 mm, and LVDT-2 and LVDT-6 shows a displacement of 3.35 mm shown in (Figure 4.18).

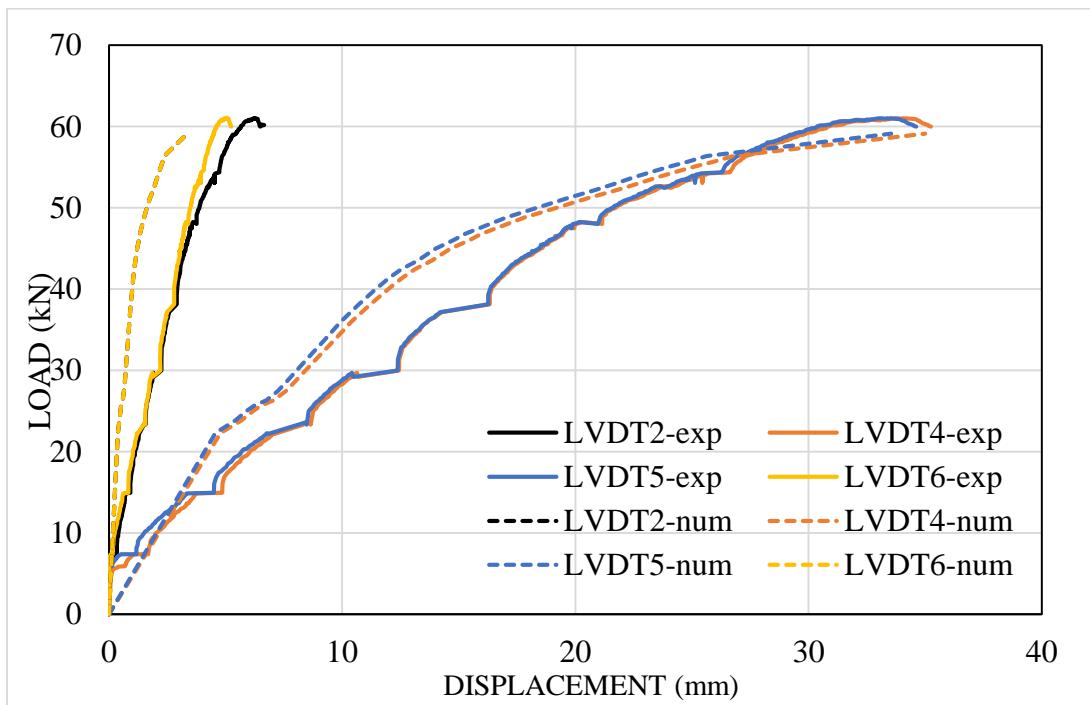


Figure 4.24. Load-displacement behavior of balconies with three IzoBlocks used per meter

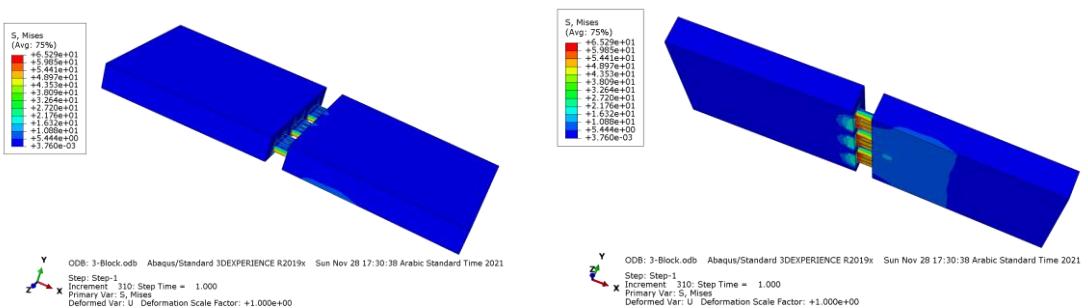


Figure 4.25. Model of the balcony with three IzoBlocks.

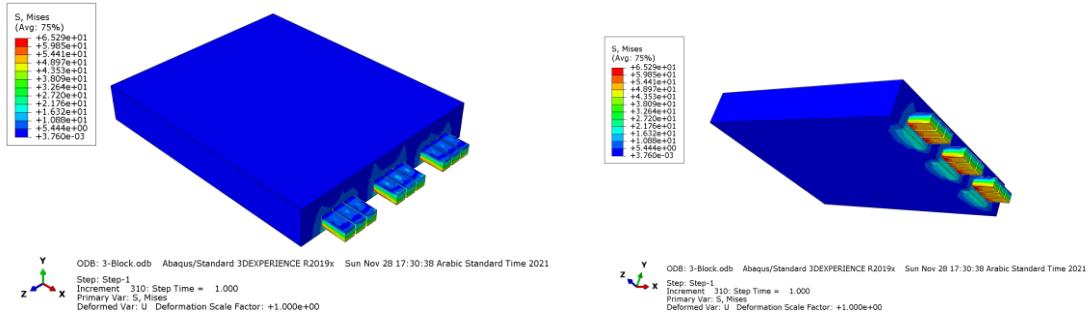


Figure 4.26. Model of the balcony with three IzoBlocks (continued).

4.6.3. Load-displacement behavior of Balcony with four IzoBlocks

The third sample (four number of IzoBlocks) was tested through applying 76.27 kN (maximum load). Also, several results were collected such as, sensor LVDT-5-num displays a displacement of 33.48 mm, whereas sensor LVDT-4-num shows a displacement of 35 mm, and LVDT-2 and LVDT-6 shows a displacement of 3.26 mm shown in (Figure 4.20).

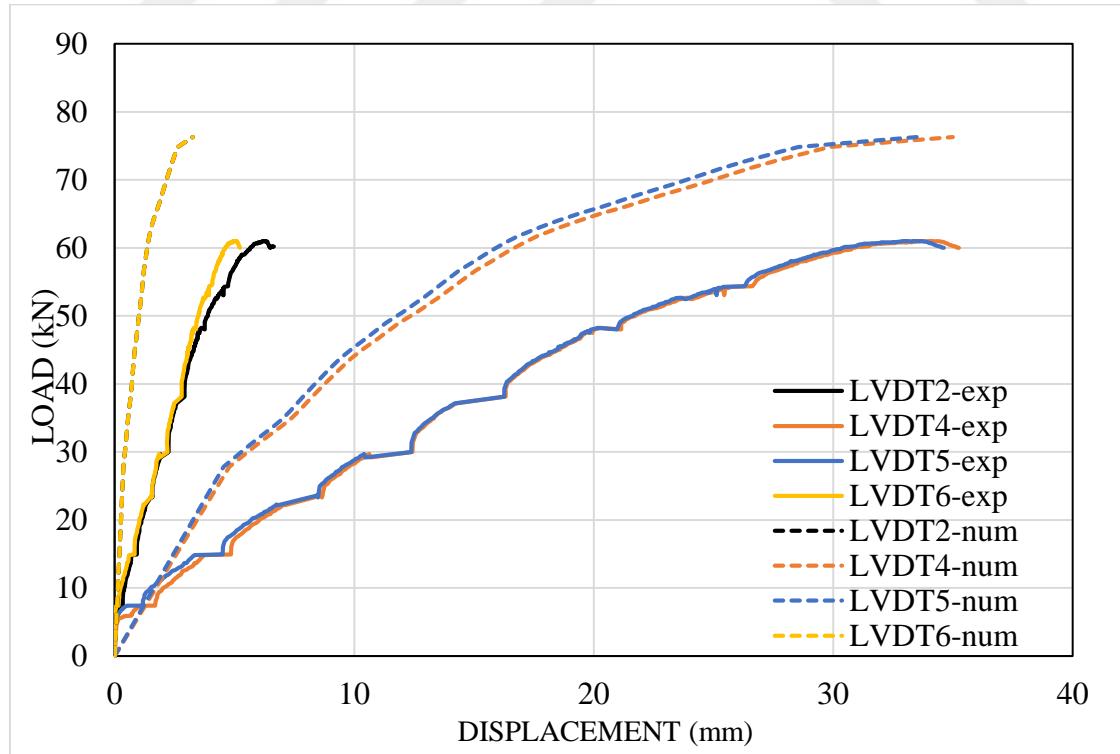


Figure 4.27. Load-displacement behavior of balconies with four IzoBlocks used per meter.

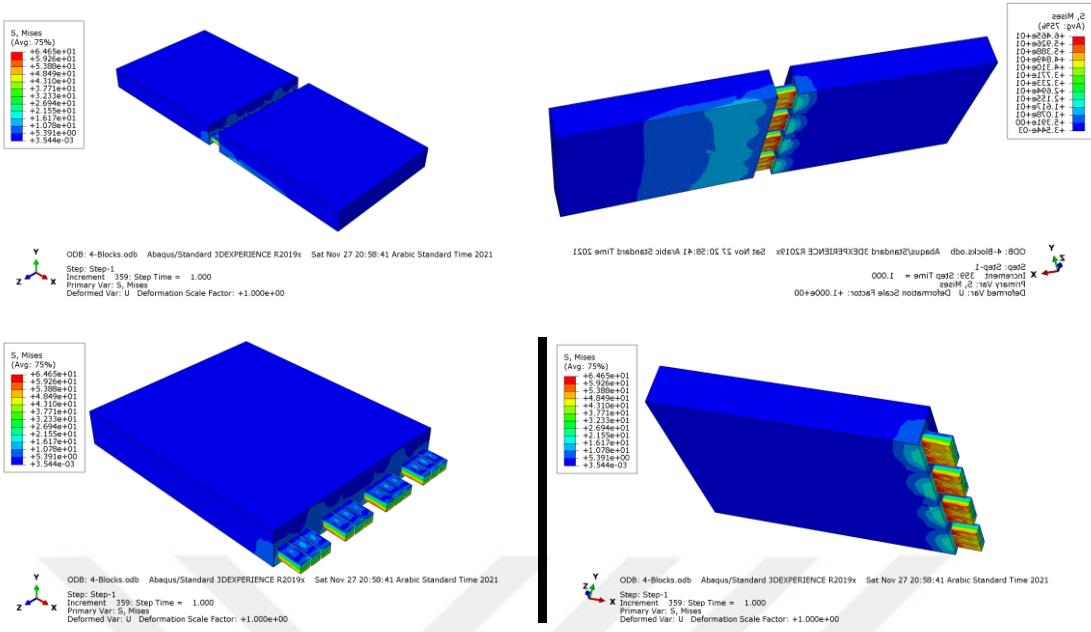


Figure 4.28. Model of the balcony with four IzoBlocks.

Table 4.2. Effect of number of IzoBlocks on edge displacement of balconies

No of case s	No of block s	Applie d loading (kN)	Displacement (mm)							
			LVDT2		LVDT4		LVDT5		LVDT6	
			Num	Exp	Num	Exp.	Num	Exp.	Num	Exp
1 st	2	41.99	3.59	---	35	---	33.5	---	3.59	---
2 nd	3	59.01	3.35	6.31	35	34.3	33.5	33.6	3.35	5.08
3 rd	4	76.27	3.26	---	35	---	33.4	---	3.26	---

4.4.7. Effect of shape of high strength concrete block inside the IzoBlocks on Load Bearing Capacity of Balconies

Shape of high strength concrete block inside the IzoBlock were changed to three shapes (square, triangle and circular) in order to find the relationship between the shape and load bearing capacity of reinforced concrete balconies. The results are discussed below.

4.4.8. Load-Bearing capacity of balconies with square-shaped high strength concrete blocks in IzoBlocks

Firstly, the shape of the blocks altered to square shape blocks and then 60 kN of load was applied on simulation sample and on the ultimate load capacity was found to be 59.1 kN. The load-displacement behavior of the balcony is given in (Figure 4.18).

4.4.9. Load-Bearing capacity of balconies with circular-shaped high strength concrete blocks in IzoBlocks

Secondly, the shape of the blocks altered to circular shape blocks and then 60 kN of load was applied on simulation sample and it has been broken under a load of 58.75 kN. The load-displacement behavior of the balcony is given in Figure 4.22.

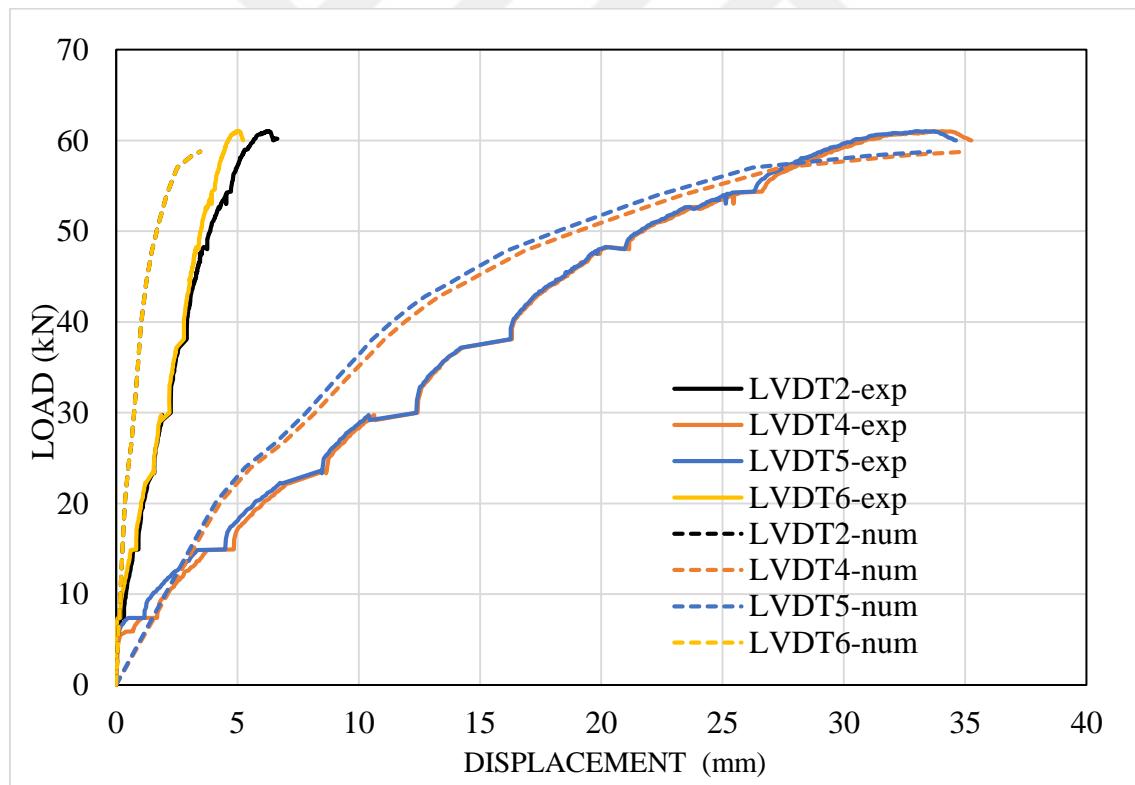


Figure 4.29. Load-displacement behavior of balconies with circular-shaped high strength concrete blocks in IzoBlocks.

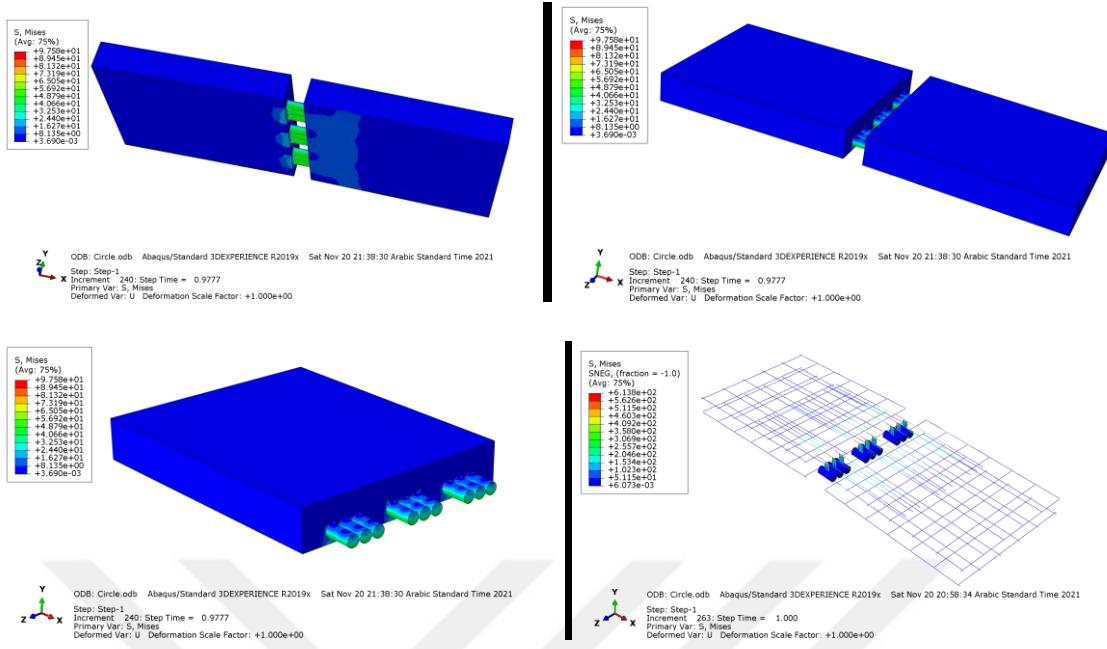


Figure 4.30. Model of the balcony with circular-shaped high strength concrete blocks in IzoBlocks.

4.4.10. Load-Bearing capacity of balconies with triangular-shaped high strength concrete blocks in IzoBlocks

Finally, the shape of the blocks altered to triangular shape blocks and then 60 kN of load was applied on simulation sample and it has been broken on 60.59 kN. The load-displacement behavior of the balcony is given in (Figure 4.24).

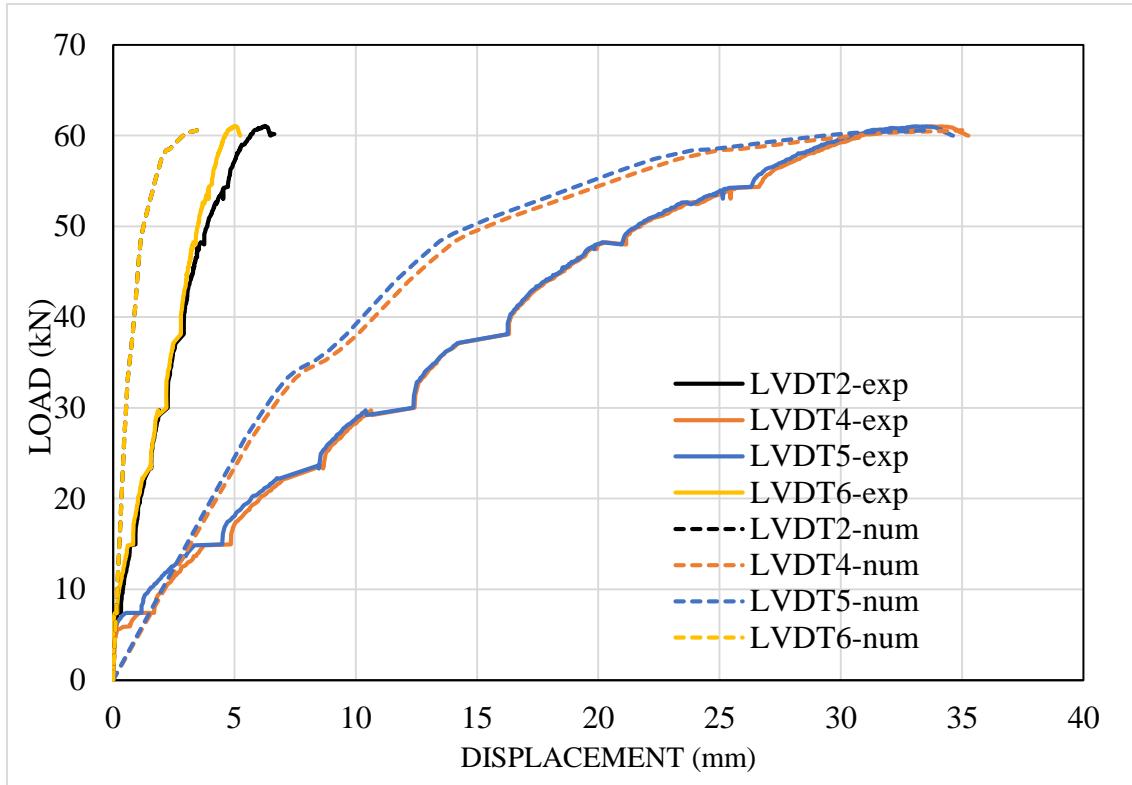


Figure 4.31. Load-displacement behavior of balconies with triangular-shaped high strength concrete blocks in IzoBlocks.

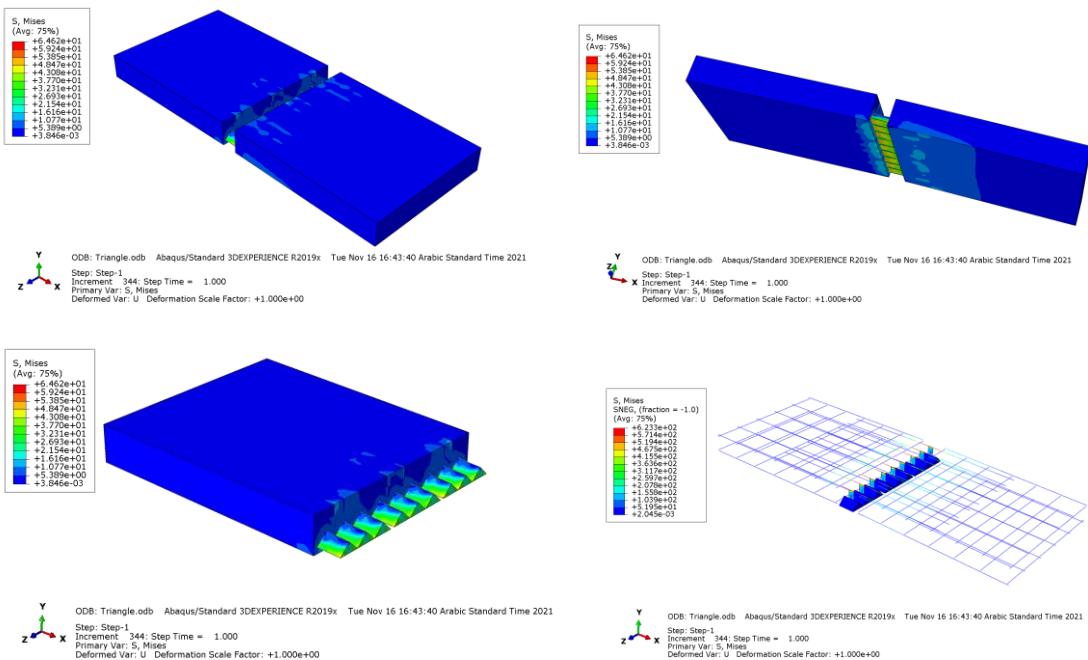


Figure 4.32. Model of the balcony with triangular-shaped high strength concrete blocks in IzoBlocks.

4.4.11. Effect of steel plate thickness on Load Bearing Capacity of Balconies

Thickness of steel plates inside the IzoBlock were changed (1 mm, 2mm and 3 mm) in order to find the relationship between the steel plate thickness and load bearing capacity of reinforced concrete balconies. The results are discussed below.

4.4.12. Load-Bearing capacity of balconies with 1mm thick steel plate inside the IzoBlocks

Firstly, the steel plate thickness changed to 1mm, so, 60.01 KN has been applied to evaluate its strength and displacement, but the sample were broken at 54.09 KN, also, sensor LVDT-5-num a simulation software Abaqus shows 29.36mm displacement, whereas sensor LVDT-4-num shows 30.66 mm displacement, and LVDT-2 and LVDT-6 shows 2.75 mm displacement, as illustrated in (Figure 4.26).

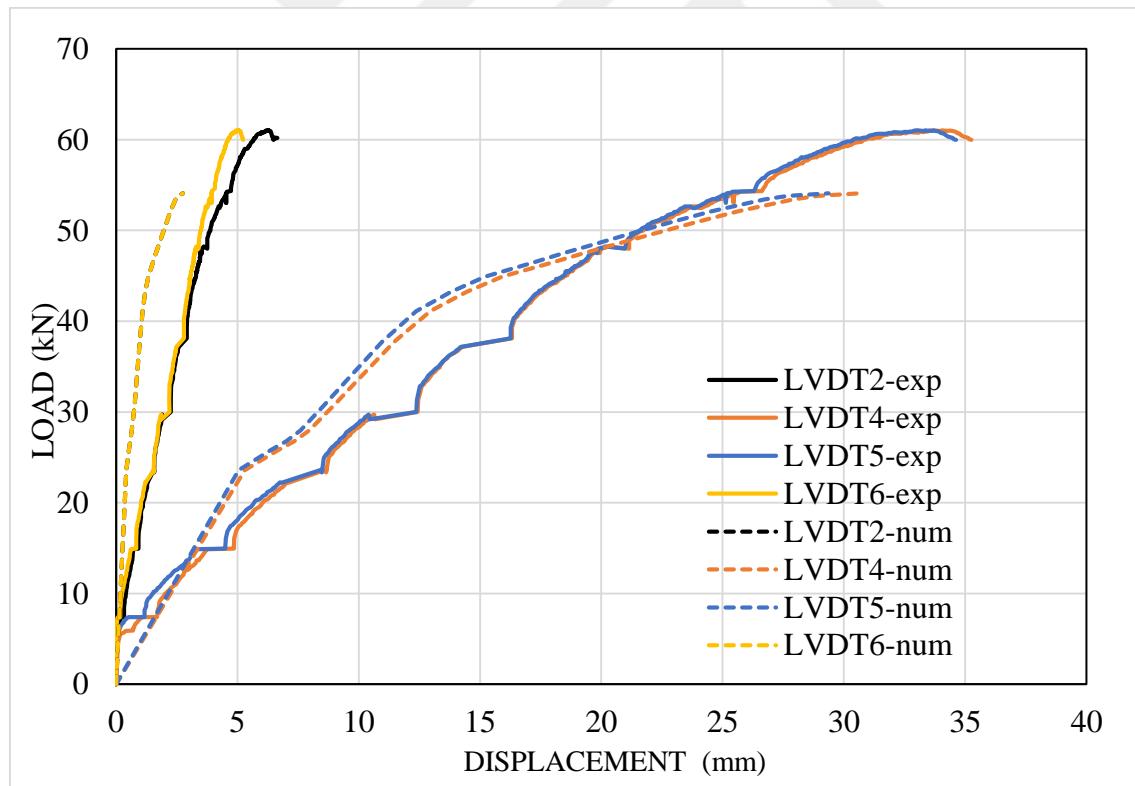


Figure 4.33. Bending test for 1mm thick steel plate in IzoBlock.

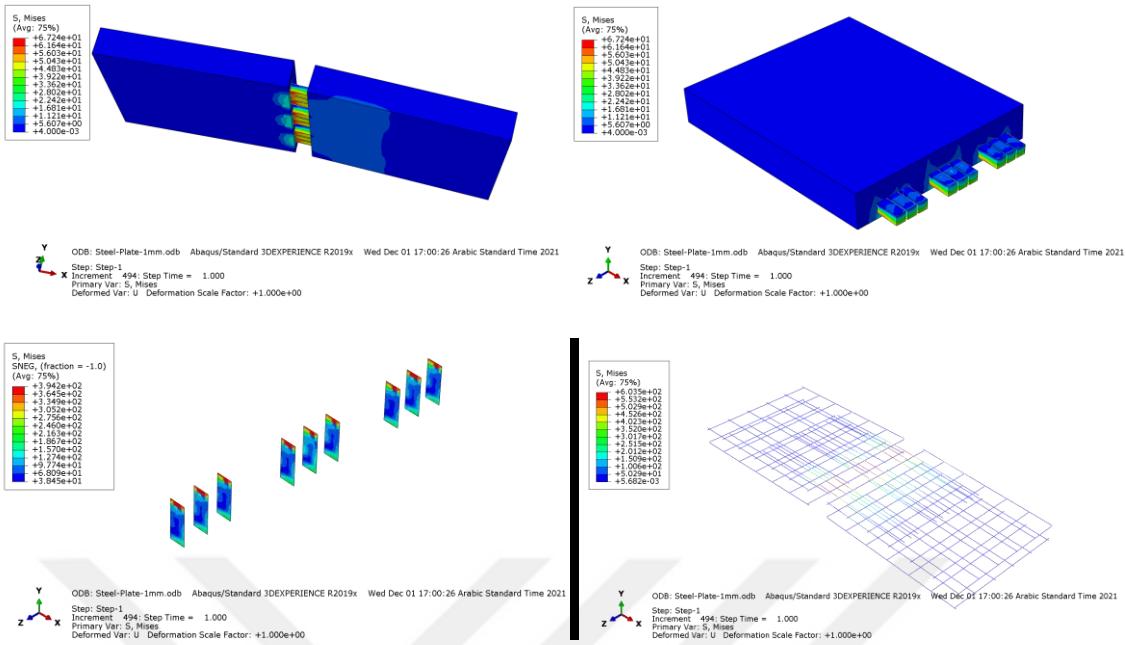


Figure 4.34. Model of the balcony with IzoBlock having 1 mm steel thick plate.

4.4.13. Load-Bearing capacity of balconies with 2mm thick steel plate inside the IzoBlocks

Secondly, the steel plate thickness changed to 2mm, so, 60.01 kN has been applied to evaluate its strength and displacement, but the sample was broken at 59.1 kN.

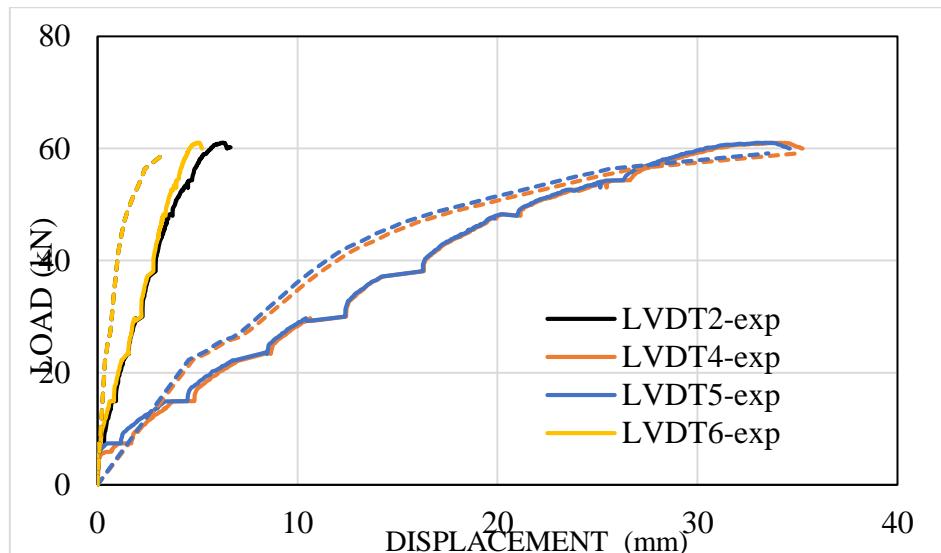


Figure 4.35. Bending test for 2mm thick steel plate in IzoBlock.

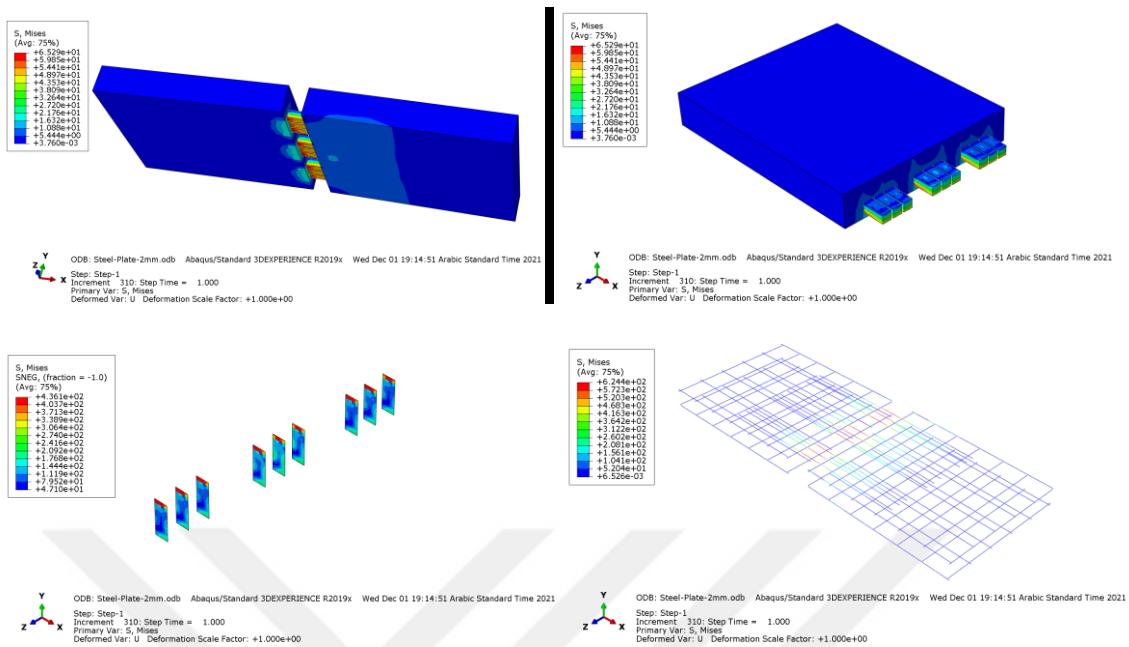


Figure 4.36. Model of the balcony with IzoBlock having 2 mm steel thick plate.

4.4.14. Result of changing steel plate thickness (3mm)

Finally, the steel plate thickness changed to 3mm, so, 60.01 kN has been applied to evaluate its strength and displacement, but the sample was broken at 54.09 kN. LVDT-5-num in simulation software Abaqus shows 29.36mm displacement, whereas sensor LVDT-4-num shows 30.66 mm displacement, and LVDT-2 and LVDT-6 shows 2.75 mm displacement as shown in (Figure 4.30).

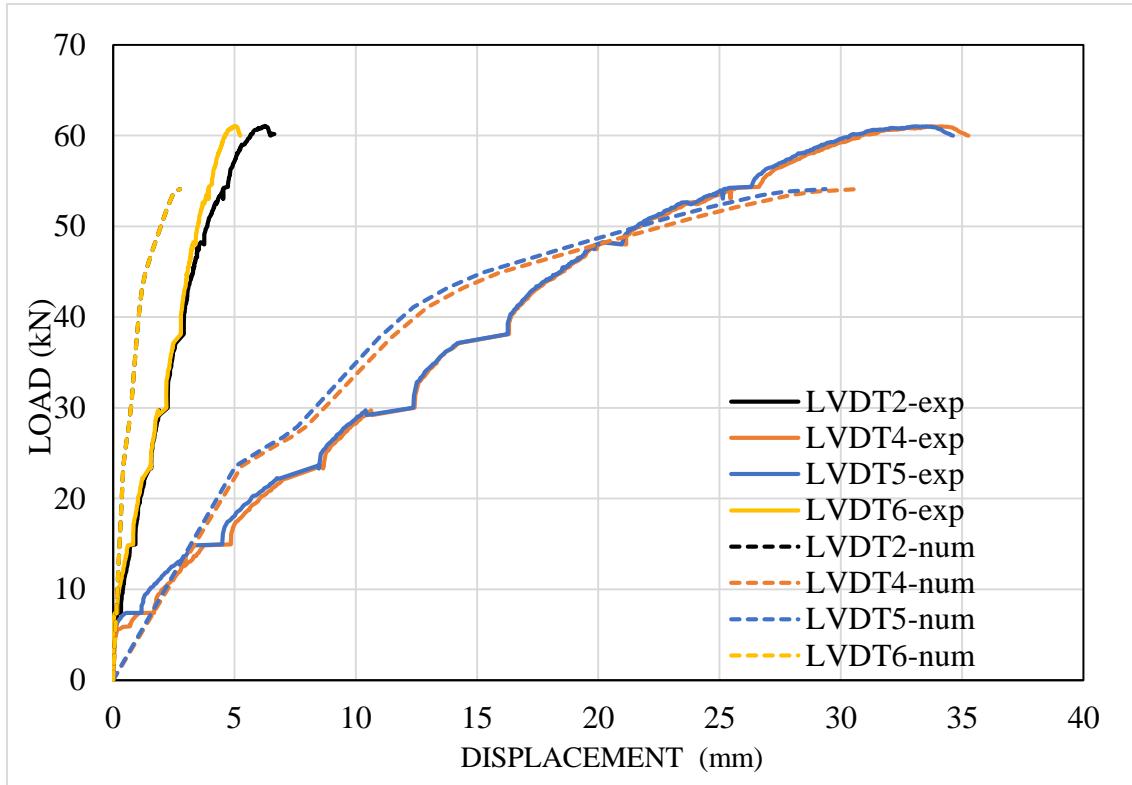


Figure 4.37. Bending test for 3mm thick steel plate in IzoBlock.

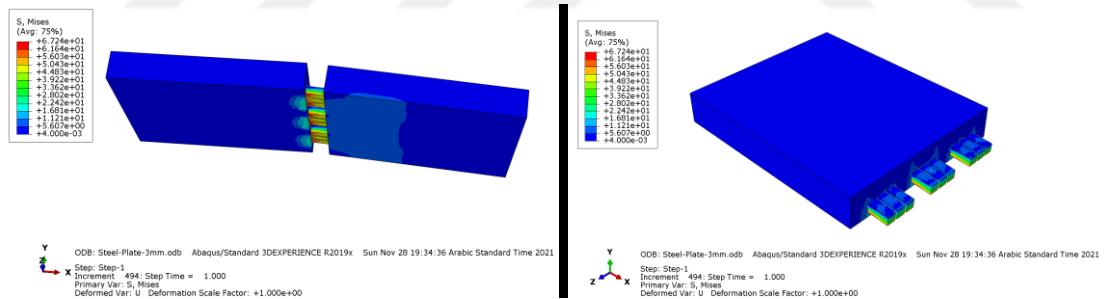


Figure 4.38. Model of the balcony with three IzoBlocks.

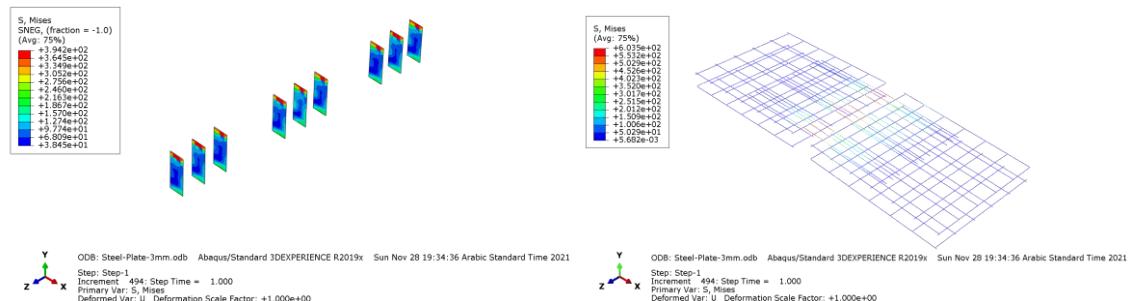


Figure 4.39. Model of the balcony with IzoBlock having 3 mm steel thick plate (continued).

5. CONCLUSION AND RECOMMENDATIONS

The result of this study indicates that the use of thermal break element in a balcony slab is necessary for overcoming thermal bridge issue in the construction of a building or a house. Many simulations have been made to perform the bending tests on three balcony slabs and the results show that the samples were able to hold a great amount of load of about 60.8 kN with respect to the displacement factor that have been investigated through analyzing the sensors that have been displaced over different areas of the balcony slab samples. Additionally, the result of this study proves that using minimum amount of high strength concrete efficiently is sufficient to withstand great loads and acts as a thermal barrier in which less thermal loss occurs. This means that using the constructed design of balcony slab sample in the construction projects that involve a balcony will help to minimize or overcome the thermal bridge issue.

The simulation results showed that using 55MPa concrete IzoBlock was optimum strength to use in balcony. However, increasing strength of IzoBlock concrete does not lead to high increases in load bearing capacity. Using different shape of concrete in IzoBlock effect the load resistance of the balcony. By using the triangular shape of concrete inside IzoBlock, the maximum load resistance was achieved. Increasing the number of IzoBlock increases the load resistance of balcony but it has a drawback because of increasing area of concrete which lead to raise conductivity. Also, using three IzoBlocks is the most efficient when considering thermal conductivity and structural resistance.

The current research looked at the effects of a special balcony slab sample configuration and construction on thermal bridge, as well as how to reduce it. The findings of this study clearly demonstrate the study's accomplishments, but some simulations and parameters are suggested for future research. The recommendations for future research include investigating the effect of other parameters, such as the use of different thermal bridge thickness and use of two IzoBlock with ultra-high strength concrete on the thermal bridge, and the use of software and model to investigate the thermal conductivity of thermal bridge with creative construction materials that aims to reduce the environmental pollution.



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(EXTENDED TURKISH SUMMARY)
(GENİŞLETİLMİŞ TÜRKÇE ÖZET)

TERMAL KIRILMA ELEMANI İLE BALKONUN DENEYSEL ÇALIŞMASI

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Binalarda enerji verimliliği giderek daha önemli hale geldiğinden, bina elemanlarının ısil ve dayanım özelliklerini doğru bir şekilde tahmin etmek gereklidir. Bu amaca ulaşmak için binalarda balkon konsollarındaki ısil kayıpların önüne geçmek için kullanılan taşıyıcı ısi yalıtımlı bileşenlerinin yük taşıma kapasitelerinin belirlenmesi gereklidir. İnovan Yapı Teknik tarafından geliştirilen, çekme çubukları ve basınç modülleri ve yalıtımlı malzemeleri, İzoBlock adlı taşıyıcı ısi yalıtımlı elemanını oluşturan ana bileşenlerdir. Balkon-döşeme bağlantısını simüle etmek için taşıyıcı ısi yalıtımlı bloğu İzoBlock'un dayanım özelliklerini, laboratuvar testlerinden toplanan verilere dayanılarak belirlenmiştir. Modellerdeki karmaşık geometrilerle yük aktarımı ve ısi yalıtımlının sağlanmış olması, daha gerçekçi iki veya üç boyutlu modellerin hesaba katılmasını gerektirecektir. Abaqus Yazılımı kullanılarak 3 boyutlu model oluşturulmuş ve farklı özelliklere sahip İzoBlock'un etkinliğini araştırmak için parametrik bir çalışma yapılmıştır.

Anahtar Kelimeler: Eğilme deneyi, Köpük, ısil kırılma, ısi köprüsü, ısil yer değiştirmeye, Yüksek dayanımlı beton.

1. GİRİŞ

1.1. Arkaplan

Mühendislik projelerinde, bina içinden dışarıya veya dışarıdan içeriye ısi akışını durdurmak veya ısi akışını azaltmak için düşük sıcaklık iletkenlige sahip elemanlar kullanılarak termal bariyerler kullanılmaktadır ki bunlar *termal kırılma* olarak adlandırılmaktadırlar. Diğer bir tanımlamayla *termal kırılma*, düşük ısi iletkenliğine sahip malzeme kullanılarak termal akışı azaltmak için balkon yapımında yaygın olarak kullanılan malzemeler bütününe verilen addır.

Bina yapılarından bir temel bölüm olarak balkon, dış ortama erişimin kolay ve hızlı bir yolunu sağlayan, binaların çatılı alanının bir uzantısı olarak yapılmakta ve kullanılmaktadır. Hemen hemen her bina ve inşaatta bulunabilmelerine rağmen, yılın büyük çoğunluğu doğal iklim koşullarının yumuşak olduğu bölgelerde daha belirgin olarak yapılarda yer almaktır (Papamanolis, 2004).

Konu üzerinde yapılan detaylı çalışmalar, ısi seviyesinin geçirgenliği ve ısinın seviye farkı, termal kırılma elemanlarına ve bunun gibi faktörlere bağlı olarak değişikliğe uğradığını ortaya koymaktadır.

- Soğuk alan ile ısi kaynağı arasındaki değişim ve üretilen ısi
- Sıcaklık iletkenliği açısından kullanılan malzeme ve elementlerin özellikleri
- İnşaatların veya binaların kesit olarak alınan alanı
- Sıcaklığın doğası gereği binalara girip çıkabilme özelliği.

Bununla beraber aşağıda da gösterileceği gibi, ısi transferi ve diğer ilgili noktalar açısından inşaat projelerine etki edebilecek birkaç belli başlı özellikler daha bulunmaktadır.

- Yüzeyde kullanılan malzemelerin iletkenliği, binaların nispi alanı, bunalara temas eden ısi kaynağı gibi faktörler açısından dikkate alınmalıdır.
- Binalarda var olan yan ısi akışı, kırımlardan geçerek ısinın binaların dışından içine veya içerdenden dışına geçmesine yol açabilecek bazı önemli noktalar da vardır.

1.1. Çalışmanın Problemi

İsı köprüleri, brüt beton balkon-döşeme bağlantıları olarak enerji tüketimi noktasında büyük bir önemi haizdir. Bu malzeme yerine daha uygun maliyetli bir alternatif bulmak mümkün olmasına rağmen, estetik, inşa edilebilirlik veya sıralama sorunları nedeniyle genellikle göz ardı edilmektedir. Dünyada genelinde bu ürünleri kullanan birkaç başarılı proje tamamlandığı gibi buna ek projelerde devam etmektedir. Bu bağlamda balkonların etkin ısı akışı ve iç mekan termal konforu üzerindeki etkileri hakkında ısı yalıtılmış açısından bir değerlendirme yapılmıştır (Murad, Doshi ve ark. 2015). Buna göre açık balkonlardan kaynaklanan enerji kaybının yanı sıra, tipik koşullarda balkon ve döşeme kenarı ısıl yalıtılmış malzemeleri kullanıldığında gerçekleştirilebilecek alan koşullandırma tasarrufları sayısal bakımından çeşitlendirilmiştir.

1.1 Çalışmanın Amacı ve Hedefi

Çalışmanın objektif yorumları aşağıdaki gibi sıralanabilir:

4. Standart sayısal teknikleri ve ABAQUS (FEM) kullanarak etkili bir balkon levhası oluşturmak için uygun bir simülasyon çalışması yapmak.
5. İnovan Yapı Teknik tarafından geliştirilen ve İzo Blok olarak adlandırılan taşıyıcı ısı yalıtılmış bloğunun mukavemetini araştırmak.
6. Isı köprüsü problemine daha az maliyetli bir çözüm sağlamak için parametrik bir çalışma yapmak.

1.2. Araştırmannın Önemi

Yapısal sıcaklık kırılma bileşenlerinin yalıtımsız bağlantılarından daha düşük sıcaklık iletkenliğine sahip olması nedeniyle toplam bina enerji tasarrufunun yüksek olacağı tahmin edilebiktedir. Isı köprüsü kullanılacak yerde yüksek mukavemet kapasiteli balkon levhası ve enaz beton alana sahip olması için optimum tasarım yönteminin belirlenmesi sonucu balkonda kullanılacak farklı yapı malzemelerinin simüle ederek sonlu bir analiz programı kullanmak. Bu bağlamda yapılarda sonlu elemanlar

programı çerçevesinde, deneysel sonuçlarla karşılaştırıldığında daha az zaman ve maliyet gerektirdiği tespit edilmiştir.

2. LITERATÜR İNCELEMESİ

Bina ve yapılarda sıcaklık köprüsü, bitişik alanlara göre gelişmiş ısı iletkenlige sahip lokalize alanlar olarak ifade edilmektedir. Bir yapı örtüsündeki normal bir termal köprü, fiziksel olarak yüksek iletkenlige sahip olduğunda, buna çelik veya betondan yapılmış operasyonel bir bağlantı örnek olarak verilebilir(Ilomets, Kuusk et al. 2016), bu durumda bu yapıdaki termal köprü izolasyon katmanı kapsamında değerlendirilebilir (Kotti, Teli et al., 2017). Böyle durumlarda binalarda ısı köprüsü olması, montaj boyunca ileri ısı transferine ve montajın sıcak tarafında daha soğuk yüzey sıcaklıklarına neden olabilecektir. Bu durmda bu termal köprü, soğuk yüzeylerde yoğunlaşmaya neden olabilir ve bu da aşağıda ele aldığımız durumlara yol açabilir: Isınma için ve serinleme için daha fazla enerji kullanımımı, yapı yönetmeliği ile çatışma, soğuk ortamlar nedeniyle huzursuzluk baş gösterebilir (O'Grady vd., 2018). Metal bileşenlerin tasarım ve kullanımımı, ahşap esaslı malzemelerin çürümesi, yüzey sıcaklığı ve kuruma potansiyelinin çeşitliliği nedeniyle iç veya dış yüzeylerde belirgin örnekler olarak karşımıza çıkabilmektedir. Diğer yandan koruma uygulamasının temelinin bozulması (yapının içinde birikme olması durumunda), form geliştirme ve ilgili refah endişelerini de beraberinde getirebilmektedir.

3. MATERİYAL VE YÖNTEMLER

Bu bölümde yer alan farklı simülasyonları harekete geçirmek için gereken tüm prosedürler ve malzemeler ile bu araştırmada kullanılan metodların bir açıklaması olarak sunulması, termal köprü sorunlarına optimum bir çözüm bulmayı amaçlayan bu çalışma için büyük mukavemetli bir balkon konstrüksiyonu meydana getirmektedir.

3.1. Yazılım Bakımından Yorumlama

Abaqus, termal köprü problemlerini çözmek için önerilen birkaç yöntemi belirlemek için kullanılan programlardan biri olarak karşımıza çıkmaktadır ki bu

program, bilinen ve kullanılan bir yöntem olarak sayısal analizler içermektedir. Ayrıca Abaqus programı, her tür büyülükteki binaların içinde ve çevresinde 3 boyutlu yük ve yer değiştirme, çevre kirliliği yayılımı, konfor kılavuzlarını tahmin etmek için uygun hesaplama yazılımlarından biri olarak bilinirliğini korumaktadır. Bu anlamda bu program, balkon levhalarında gerçekleştirilen çelik desteklerin özel yerlerini analizde kullanılmaktaydı. Bu yöntemin kullanılmasıyla balkonun her bileşeni hesaplamaya dahil edilmiştir ki bunlar, (çelik destek, sıcak bir kırılma ile engellenen çıktı parçasının önü, köpük kısımları ve çıktı bölümünün sıcak koruması) gibi bileşenlerdir.

Bürün bunlara ek olarak ek olarak, nokta termal köprüleri üzerindeki hareket, karmaşık yapıları genellikle doğrusal ısı köprülerinde varsayıldığı gibi daha basit yorumlamalara izin vermediğinden, yalnızca 3B sabit eleman modellemesi yoluyla alınabilmisti. Çalışma, elinizdeki tezin amacına uygun olarak, balkonun termal kırılma elemanlı sistem örneklemi seçilmiş ve kararlı durum termal koşullar altında Abaqus sonlu eleman analizi kullanılarak yorumlanmıştır. Çalışma, noktasal termal köprülerin istenmeyen yer değiştirme üzerindeki etkisini analiz etmek için, termal köprüsü şemali balkonların tasarım sürecinde analiz edilebilecek en önemli parametrelerini uygulanan tam yük altında ele almıştır. Yine çalışmada malzeme karakteristiği ve boyutu simüle edilmiş balkonun fiziksel parametrelerini etkileyen faktörler, laboratuvardaki pratik testten alınan sonuçlarla karşılaştırarak bir senteze gidilmiştir.

3.2. Kavramsal Açıklama

Bu bölümde Abaqus'ta malzemelerin nasıl tanımlanacağı açıklanmış, bunun sonucunda sağlanan malzemelerin her birinin kısa açıklaması eklenmiştir.

Abaqus programları, kendisine has bir özellik olarak daha gelişmiş analizlerle ilgili daha fazla ayrıntı içerebilmektedir.

Simülasyonlar için İzo Blok'un nihai basınç dayanımı (fcu) 35 ile 75 MPa arasında değişebilmektedir. Balkonların verim bakımından gerilmesi 0,0044, nihai gerilme noktaları ise 0,008 olarak ölçülmüştür. Elastisite ve beton hasar plastisite parametreleri de dahil olmak üzere diğer tüm parametreler Tablo-1'de ele alınmaya çalışılmıştır. Elastik olmayan (veya ezilme) gerilme, çatlama gerilme, sıkıştırma hasarı dahil çelik özellikleri Tablo-2'de gösterilmeye çalışılmıştır.

Tablo 3.1. Elastikiyet ve beton hasar plastisite parametreleri

Absolute zero	-273.15 °C
Acceleration of gravity	9.8066 m/s ²
Atmospheric pressure	0.10132 × 10 ⁶ Pa
Stefan-Boltzmann constant	$5.669 \times 10^{-8} \text{ W/m}^2 \text{ }^{\circ}\text{K}^4$ where $^{\circ}\text{K} = ^{\circ}\text{C} + 273.15$

Tablo 3.2. Çelik Özellikleri

Properties	SI unit
Conductivity	50 W/m °C
Density	7800 kg/m ³
Elastic modulus	207 × 10 ⁹ Pa
Specific heat	460 J/kg °C
Yield stress	207 × 10 ⁶ Pa

Bu modelde kullanılan çelik ve beton malzemelerin özellikleri Tablo 3 ve 4'te gösterilmiştir. Concrete hasarlı plastisite modelindeki girdi değerleri için standart bir veri elede edilmediğinden, girdi verilerinin güvenilirliği analize tabi tutulmamıştır.

Tablo 3.3. Beton bir yapıda özellikler

Elasticity parameters	Young's modulus, E	26700 Mpa
	Poisson's ratio	0.2
Concrete damage plasticity (CDP) parameters	Dilation angle, ψ	31°
	Eccentricity, ξ	0.1
	Biaxial stress ratio, σ_b/σ_c	1.16
	Second stress invariant ratio on tensile meridian, k_c	0.67
	Viscosity parameter, μ	0

Tablo 3.4. Çelik bir donanımda malzeme özellikleri

Elasticity parameters	Young's Modulus, E	2.1×10^5 Mpa
	Poisson's ratio, ν	0.3
Plasticity parameters	Tensile yield strength, f_y	435 MPA
	Tensile yield strain, ϵ_y	0.0021
	Tensile ultimate strength, f_u	580 Mpa
	Tensile ultimate strain, ϵ_u	0.12

3.3. İzo Blok Tanımı

Çelik postun çelik çubuğa bağlanmasıyla oluşan bir bağlanma şeklidir ki buna (yüksek mukavemetli takviye çubuğu) denilmektedir. Kırpma kapasitesi amacıyla kullanılan bu levha, levha boyutu 4cm x 9.8cm (W*H) cm olup, 3mm (T) mm kalınlığındadır ve şekil 3'te izah edildiği gibidir. 4. Çelik levhanın alt kısmı dışlidir. Yüksek mukavemetli beton, küpte süreksizliği önlemek için 3,3 cm derinliğinde ve 5*5cm boyutunda uygulanmaktadır.

Her bir yüksek mukavemetli beton numunesinin boyutu, Şekil (3.2)'de gösterildiği gibi olup, tablo 3'e göre 5x5x12 cm ebatındadır.

Bu işlemden sonra yüksek mukavemetli betonda 75 kalite donatı çubuğu (yüksek mukavemetli çubuk) ve 60 sınıf donatı çubuğu (normal mukavemetli çubuk) ve kaynak bağlantısı ile donatı 3.2'de gösterildiği gibi yapılmıştır.

3.4. Model Açıklaması

Bu tezde iki tip model ele alınmaktadır: Bunlar İzo Blok ve konvansiyonel balkonlu sistem olarak iki tanedir. Ele aldığımız modellerin ilki, *normal beton balkon modeli* olup, söz konusu modelin meydana getirilmesinde Abaqus yazılımı istihdam edilmiştir. Burada kullanılan model balkon ölçülerini (1 m genişlik, 1.25m uzunluk) ile taban destekli balkon toplam uzunluğu 2.5 m olup, 12mm çapında ve 20 cm'lik iki katman şeklinde ayrılmıştır.

Bu modellemede kullanılan ikinci örnek de ise İzo Blok termal tuğla modelidir. Nitekim bu tezde ele alınan temel problemin, 1m genişliğindeki büyük sarkan balkonu ifade eden deneysel bir projeden olduğu dile getirilebilir. Bu çalışmada bina etkisi için, sarkan yapının titreşim frekansını belirlemek için sarkma uzunluğunun 1,2 m'ye ulaşması planlanmıştır. Bu bağlamda araştırma, konsol konstrüksiyonunun doğrusal olmayan sonlu elemanlar belirlemesini gerçekleştirmek için ABAQUS yazılımından faydalananmaka ve yükü etkileyen ana faktörleri elde etmeye çalışmıştır. Bununla beraber gerekli yöntemlerin uygulanmasıyla konsol yapının yer değiştirme değeri ve tasarım için makul öneriler de deneysel bazda sunulmaya gayret edilmiştir. Çalışmada ele alınan modelleme ve süreç, birkaç aşamadan geçerek oluşturulmuştur: Birincisi, modelleme

analizi için konsol balkon panosunun küçük bir çıkıştı boyutunu seçmek, ve bu ilk modellemede konsol levhasının sabit tarafının uzunluğu 1.0 metre, konsol uzunluğu 1.25 metre, levha kalınlığı 180 mm ve beton örtü tabakası kalınlığı 25 mm olarak belirlemek ve kesit boyutu ile donatıyi hazır hale getirmektir. Bu modelleme Şekil 3.4'de gösterilmiştir. Ağ yapma sistemi, ABAQUS ile elde edilemeye çalışılırken, eldeki yapı elemanın kesit alanı değiştirilerek donatının çapı elde edilmeye çalışılmıştır. Bu modellemede kuvvet çelik çubuğu $\varphi 12 @ 200$ ve dağıtım çubuğu $\varphi 12 @ 200$ olarak ayarlanmıştır. Yapı donatı ve beton arasındaki ağı, bir ucta sabit, diğer kenarlarda serbest sınır koşulu ile yerleşik alan ayarlarının etkileşimi ile elde edilmeye çalışılır. Modelleme, Şekil 3.6'da gösterilen sonlu eleman ABAQUS modeli olarak analiz edilmiştir.

Balkon numunesinin iç ve dış donatıları Eurocode'lara göre dizayn edilmiştir(EN 1992-1-1, 2004), (EN 1993-1-1, 2005) ve (EN 1993-1-4,2006)(Lennon ve Moore 2007). Yine uygulanan yüze direnç için 12 mm boyutunda 60 kalite çelik çubuk kullanıldı. Bununla beraber bu büyük balkon modelinde üç adet İzo Blok yerleştirilerek örenklem gerçekleştirilmiştir. Son olarak bu çalışmada izo Bloklar arası boşluk 0,035 w/mK yün izolasyon ile doldurulmuştur (TS EN 13501-1/Class A.).

3.5. Araştırmancın Programı

Çalışmanın programında balkona statik yük uygulanarak dört nokta eğilme testi modellendiğinde balkonun deformasyonunu göstermek için balkon simule edilmiştir. Daha sonra model sonuçları ile deneysel olarak elde edilen sonuçlar karşılaştırılarak analiz edilmiştir. Proses simülasyonlarında dört groove (G1, G2, G3, G4) bölünür. Bundan dolayı ilk groove G1 beton basınç dayanımı değiştirilmiştir. Bu şekilde her beton tipi için Tablo-5'te gösterildiği gibi beş model oluşturulmuştur. İlkinci gropede benzer modelde G2 blok sayısı değiştirilmiş, ilkinde iki ve dört numaralı İzo Blok'lar kullanılmıştır. Üçüncü groove'de yüksek dayanıklı betonun G3 şekli üç şekele (kare, üçgen ve daire) şeklinde değiştirilmesine olanak sağlandı. Son groove G4 çelik levha kalınlıkları üç tip (1mm, 2mm, 3mm) olarak değiştirilerek veriler alınmaya çalışıldı.

- G1 → Basınç mukavemetinin değiştirilmesi
(35Mpa,45Mpa,55Mpa,65Mpa,75Mpa)
- G2 → Blok sayısının değiştirilmesi (2*3blocks, 3*3 blocks, 4*3blocks)

- G3 → Yüksek mukavemetli beton izo bloğun şeklärinin (kare, üçgen, dairesel) olarak değiştirilmesi.
- G4 → Çelik levhanın kalınlığının değiştirilmesi (1mm, 2mm, 3mm)

3.6. LVDT dağılımları

Değişik konumlarda beton balkonun yer değiştirmesini ölçmek için dört LVDT kullanılır. Yedek olarak çok hassas LVDT (4&5) örneklemi serbest ucuna sabitlenir, LVDT (2&6) balkon-lento-duvarlar-zemin-termal mola üzerine sabitlenerek gerçekleştirilir. Daha sonra LVDT'ler balkonun her iki ucuna sabitlenerek şekil 3.8'de gösterildiği gibi hassas bir şekilde termal köprü bölgesinin üstüne monte edilir.

3.7. Yükleme Hızı, Boyut, Şekil ve Blok Sayısının Balkonların Yük Kapasitesine Etkisi

3.7.1. İzo Blok basınç dayanımının balkona etkisi

Daha önce ele alındığı gibi birinci modelde (G1) basınç mukavemeti değiştirilmiş ve aşağıda tartışılacığı gibi çeşitli sonuçların elde edilmesine neden olmuştur. Bununla beraber model C35, C45, C55, C65 ve C75 dahil olmak üzere birçok farklı karşılaştırmalı güç eklenerek deneysel alanda gerçekleştirilmiştir. Farklı gerinim oranları ile statik ve dinamik yükleme testleri için numune boyutları, maksimum basınç dayanımı şeklinde konumlandırılmıştır. Statik tek eksenli basınç dayanıklılık durumları, ~35 MPa, ~45 MPa ~55 MPa ~65 MPa ve ~75 MPa olan beş beton sınıfı sırasıyla C35, C45, C55, C65 ve C75 olarak gösterilmiştir.

3.7.2. İzo Blok sayısının bağlayıcı yer değiştirmeye etkisi

Yukarıda beyan edildiği üzere numunede üç farklı izo blok kullanılmıştır ki birinci numune 3 İzo blok, ikinci numune 4 İzo blok ve üçüncü numune 2 İzo blok şeklindedir. Bu bölümde bir bloğun izo blok sayısı değiştirilerek verilmiştir. Şekil 3.12 ve 3.13'te gösterildiği gibi numune bire bir eklenir 4 İzo blok olduğunda numune 3'ten bir İzo blok çıkarılır. Bu durmda geriye 2 İzo blok kalmaktadır. Bu modellemede İzo blok'u değiştirmeye yönelik bir çalışma ile mukavemet ölçme durumu vardır.

3.7.3. Yer değiştirmenin blok bağlamanın üzerindeki etkisi

Çalışma kapsamında sunulan modelin güvenilirliğini değerlendirmek ve analizlerde bulunmak için sayısal simülasyonlar kullanılmıştır. C55 olarak bilinen, 50x50 mm (kare ve 120 mm yükseklik) şeklindeki yüksek mukavemetli betonun eğilim deneylerini içeren (deneysel) çalışmalar Şekil 3.14'de gösterildiği gibi yerine getirilmiştir. Bu bölüm içerisinde bloğun şekli ki üçgen şekil (Taban= 10 cm- yükseklik= 5 cm) ve dairesel şekil ($R= 2.82$ cm) simülasyonları dahil olmak üzere değişiklik yapılarak gerçekleştirilmiştir. Ayrıca üçgen ve dairesel şeklin kesit alanı aynı olmuştur. Şekil 1'de gösterilen kare kesit alanı bunu göstermektedir. (3.15 ve 3.16) maddelerinde belirtilen deney numunesi ile değişmekte olan eğilme mukavemeti ve maksimum basınç mukavemeti, Bölüm 2'deki Tablo 3 ve 4'te verilmeye çalışılmıştır.

3.7.4. Kalınlık kesme plakası ve bunun bağlayıcı yer değiştirme üzerindeki etki

Bu modellemede sayısal olarak belirtilen FE kodu için Abaqus 2019 ve onun açık çözümüsü için Abaqus/Explicit kullanıldı. Abaqus sisteminde yer alan standart üç beton yapı modeli arasından çelik levha (kesme levhası) ele alınmıştır. Bu deneylerde kullanılan levhanın boyutu 40 mm en ve 90 mm yükseklik ile 2 mm kalınlık (deneysel) şeklinde kullanılmıştır. Yine bu çalışma çerçevesinde simülasyonda kesme levhasının kalınlığını değiştirilerek Şekil 3.17'de gösterildiği şekliyle 1 ve 3mm olarak kullanılmıştır. Çünkü bu açık çözümü ile hem sıkıştırma hem de çekme plastik davranışlarını simüle edebilen tek model olarak tespit edilmiştir. Test bağlama yer değiştirmesinin simülasyonu sırasında, nispeten şiddetli hasar nedeniyle sayısal kararsızlık sorunları yaşadığı doğrulanmıştır. Bu çerçevede, bu problemle başedebilmek için sonlu elemanların ağız

parçacıklara otomatik olarak dönüştürülmesi ki bu da “Düzeltilmiş Parçacık Hidrodinamiği (SPH)” yöntemi olarak adlandırılmaktadır, devreye sokulmuştur. Bu çalışmada sadece Abaqus'ta yer alan standart malzeme modelleri kullanılmış ve birkaç gün içinde sonuç alınmasını sağlayan basit modellemeler devreye alınmıştır.

4. SONUÇ VE TARTIŞMA

Bu bölüm çerçevesinde, tezde ele aldığımız balkon levhasının eğilim, basınç dayanımını simüle etme deneyi ve hesaplamalı tekniklerle ortaya konulan modellemenin, yazılımlar kullanılarak analiz ve sonuçlarının ele alındığı bölüm olmuştur. Nitekim ele aldığımız bu deneysel çalışmalar, Türkiye'deki laboratuvarlarda yapılmıştır. Bununla beraber 3. bölümde bahsedilen köpük, çelik ve diğer elementlerin özellikleri de İzo Blok kullanılarak farklı beton dayanımları üzerinde denemeye tabi tutulmuştur. Yine bu çalışma çerçevesinde köpüğün mukavemetinin daha az olduğu bir modelleme olarak, köpük gözardı edilmiş ve yapısal eleman ile iletkenlik bu çalışmada incelemeye tabi tutulmuştur. Bununla beraber çalışma homojenliği sağlamak için betona çelik eklenerek çalışma devam ettirilmiştir. Bu kapsamda çelik, balkon döşeme yapımında beton ile iyi bir bağ kuvveti bir araya getirebilmektedir. Modellemede 12 beton balkon döşeme yapısı eğim testine tabi tutularak simüle edilmiştir. Bu bölüm kapsamında, eğme test elemanları ile yapının mukavemetini ve yer değiştirmesini değerlendirmenin sonuçlarını analiz edilerek tartışılmıştır. Çalışmada dört kategorideki termal tuğla balkon plakalarına eğme testi uygulanmış, testlerin sonucu, ek A'daki tablo 4.1, 4.2 ve 4.3'te gösterilmiştir.

4.1. Model normal beton balkon döşeme yapısı için eğme testi

Model Normal beton balkon tipi örneklemde, normal beton balkon modeli oluşturmak için Abaqus yazılımı kullanılmıştır. Modellemede yer değiştirme durumu Şekil 4.1'de gösterilmiştir. Bu cetvelde farklı çizgiler ve renklerle temsil edilen testin sonuçlarını ayrıntılı bir şekilde gösterilmektedir. Balkon döşeme konstrüksiyonu içerisinde her sensör belirli bir noktaya hareket ettirilir. Modellemede kullanılan sensör, daha fazla yük uygulandığında en büyük yer değiştirme kaymasını veri olarak sunar.

LVDT-5 sensörüne 56,18 KN yük verildiğinde 32,56 mm yer değiştirmeye gösterirken, LVDT-4 sensörü 34,03 mm yer değiştirmeye ve LVDT-2 56,18 KN ağırlık uygulandığında 2,76 mm yer değiştirmeye göstermektedir. Şekil 4.2'de bu durum gösterilmiştir. Yeşil renkle gösterilen LVDT-6 durumunda ise 56,18 KN'lik bir yük, 2,76 mm'lik bir yer değiştirmeye ile modellenerek gösterilmiştir.

4.2. Deneysel Model İzo Blok termal tuğla beton balkon döşeme yapısı için eğme testi

Ele alınan bir beton balkon levhasının dayanma mukavemeti Şekil 4.3'te gösterilmiştir. Şekildeki farklı çizgiler ve renklerle temsil edilen yerler, testin sonuçlarını göstermektedir. Balkon döşeme konstrüksiyonu içerisinde her sensör belirli bir noktaya hareket ettirilir. Bu sensör, daha büyük yükler uygulandığında en büyük yer değiştirmeye kaymasını göstermiştir. LVDT-5 sensörüne 60,01 KN yük verildiğinde 30,38 mm yer değiştirmeye gösterirken, LVDT-4 sensörü 30,9 mm ve LVDT-2 60KN ağırlık uygulandığında 5,65 mm yer değiştirmeye şekil 4.4.'te gösterilmiştir. Yeşil renkle gösterilen LVDT-6 durumunda, 60 KN'lik bir yük 4,61 mm'lik bir yer değiştirmeye ile sonuçlanmıştır.

4.3. Model İzo Blok termal tuğla beton balkon döşeme yapısının etki basınç dayanımı durumları için eğilme

Bir beton balkon levhasının dayanım deplasmanı Şekil 4.4'te gösterilmektedir. Farklı çizgiler ve renklerle temsil edilen testlerin sonuçlarını gösterir. Balkon döşeme konstrüksiyonu içerisinde her sensör belirli bir noktaya hareket ettirilir ve bu sensör, daha büyük ağırlıklar uygulandığında en büyük yer değiştirmeye kaymasını göstermektedir.

4.4. Model İzoBlock termal tuğla beton balkon döşeme yapısının etki numarası blokları kasaları için eğilme testi

4.4.1. İzo Blok Sayısının Değiştirilmesinin Sonucu

Yukarıda da ele alındığı gibi iki adet İzo blok değiştirilerek simülasyon örneklerine maksimum yük uygulanmıştır. İlk numune (iki adet İzo blok) 60.01 Kn uygulandıktan sonra 41.99 KN'de kırıldığı tespit edilmiştir. Bununla, LVDT-5-num sensörünün bir simülasyon yazılımı Abaqus'un 33,58 mm'lik bir yer değiştirme gösterdiği, buna karşın LVDT-4-num sensörünün 35 mm'lik bir yer değiştirdiği ve LVDT-2'nin 3,59 mm'lik bir yer değiştirdiği gibi çeşitli sonuçlar saptanmıştır. Bu durum Şekil 4.16'da gösterilmiştir. Ayrıca, simülasyon sonuçları ile deneysel sonuçlar karşılaştırıldığında, veriler oldukça farklı çıkmaktadır, Çünkü deneysel numunedeki basınç dayanıklılığı 55 Mpa ve sensör LVDT-exp (2,4,5 ve 6) sonucu (5.65 - 30.9 mm, sırasıyla 30,38 ve 4,61 mm) şeklindedir. Bu bileşenler, tam satır exp ile Şekil 4.16'da gösterildiği gibi dizilmiştir.

4.4.2. Üç sayıda İzo blok değiştirmenin sonucu

Daha önce de geçtiği gibi iki adet İzo blok değiştirilerek simülasyon örneklerine maksimum yük uygulanmıştır. İkinci numune olarak üç adet İzo blok 60.01 Kn uygulandıktan sonra 59,1 KN'de kırılmıştır. Ayrıca, LVDT-5-num sensörünün bir simülasyon yazılımı Abaqus'un 33,54 mm'lik bir yer değiştirme gösterdiği, buna karşın LVDT-4-num sensörünün 35 mm'lik bir yer değiştirdiği ve LVDT-2 ve LVDT-6'nın bir yer değiştirdiği gibi çeşitli sonuçlar toplanmıştır. Şekil 4.18'de gösterilen 3.35 mm'lik yer değiştirme bu modellemeye göstermektedir. Bununla beraber simülasyon sonuçları ile deneysel sonuçlar karşılaştırıldığında, deneysel numunedeki basınç dayanımı 55 Mpa ve LVDT-exp (2,4,5 ve 6) sensörünün sonucu (5.65 mm, 30.9 mm) olduğu için veriler oldukça farklı saptanmıştır. 30,38 mm ve 4,61 mm) sırasıyla tam satır exp ile bir Şekil 4.18'de gösterildiği gibidir.

4.4.3. Dört adet İzo bloğu değiştirme ve elde edilen sonuç

Bundan önceki konularda dephinildiği gibi iki adet İzo blok değiştirilerek simülasyon örneklerine maksimum yük uygulanarak bir deney gerçekleştirilmiştir. Üçüncü numune olarak (dört adet İzoblok) 76.27 KN (maksimum yük) uygulanarak test

edilmiş, buna ek olarak LVDT-5-num sensörünün bir simülasyon yazılımı Abaqus'un 33,48 mm'lik bir yer değiştirme gösterdiği, buna karşın LVDT-4-num sensörünün 35 mm'lik bir yer değiştirdiği ve LVDT-2 ve LVDT-6'nın bir yer değiştirdiği gibi çeşitli sonuçlar analiz edilmiştir. Bu analizler, Şekil 4.20'de gösterilen 3.26 mm'lik yer değiştirme modelinde de gösterilmiştir. Bu modellemeler ile birlikte, simülasyon sonuçları ile deneyel sonuçlar karşılaştırıldığında, deneyel numunedeki basınç dayanımı 55 Mpa ve LVDT-exp (2,4,5 ve 6) sensörünün sonucu (5.65 mm, 30.9 mm) olduğu için veriler oldukça farklı olarak izlenmiştir. 30,38 mm ve 4,61 mm) sırasıyla tam satır exp ile bir Şekil 4.20'de gösterildiği gibidir.

4.5. Değişen blok şekillerinin sonuç ve verileri

Şekil 4.3'te gösterilen bir beton balkon levhasının dayanım yer değiştirmesi, farklı çizgiler ve renklerle temsil edilen testlerin sonuçlarını temsil eder. Balkon döşeme konstrüksiyonu içerisinde her sensör belli bir noktaya hareket ettiği gözlenmiştir. Bu sensör, daha fazla yük uygulandığında en büyük yer değiştirme kaymasını göstermiş, Izob lok şekillerinin değiştiği yerlerde aşağıda tartışıldığı gibi üç farklı durum ortaya çıkmıştır.

4.5.1. Kare şekilli blokların uygulama sonucu

Başlangıç uygulamalarında blokların şekli kare şekilli bloklara dönüştürülmüş ve daha sonra simülasyon örneğine 60 KN yük uygulanmış ve 59.1KN'de kırılmıştır, sensör LVDT-5-num a simülasyon yazılımı Abaqus 33.54mm yer değiştirmeyi göstermektedir. Buna ek olarak LVDT-4-num sensörü 35 mm yer değiştirme gösterirken, LVDT-2 ve LVDT-2, Şekil 4.18'de gösterildiği gibi 3.35 mm'yi gösterir. Ayrıca, simülasyon sonuçları ile deneyel sonuçlar karşılaştırıldığında, deneyel numunedeki basınç dayanımı 55 Mpa ve LVDT-exp (2,4,5 ve 6) sensörünün sonucu (5.65 mm, 30.9 mm) olduğu için veriler oldukça farklıydı. , 30,38 mm ve 4,61 mm) sırasıyla tam satır exp ile bir Şekil 4.18'de gösterildiği gibidir.

4.5.2. Daire şeklindeki blokların uygulama sonucu

Başlangıç uygulamalarında blokların şekli daire şekilli bloklara dönüştürülmüş ve daha sonra simülasyon örneğine 60 KN yük uygulanmış ve 59.1KN'de kırılmıştır, sensör LVDT-5-num a simülasyon yazılımı Abaqus 33.54mm yer değiştirmeyi göstermektedir. Buna ek olarak LVDT-4-num sensörü 35 mm yer değiştirme gösterirken, LVDT-2 ve LVDT-2, Şekil 4.18'de gösterildiği gibi 3.35 mm'yi gösterir. Ayrıca, simülasyon sonuçları ile deneysel sonuçlar karşılaştırıldığında, deneysel numunedeki basınç dayanımı 55 Mpa ve LVDT-exp (2,4,5 ve 6) sensörünün sonucu (5.65 mm, 30.9 mm) olduğu için veriler oldukça farklıydı. 30,38 mm ve 4,61 mm) sırasıyla tam satır exp ile bir Şekil 4.18'de gösterildiği gibidir.

4.5.2. Üçgen şekilli blokların uygulama sonuçları

Üçüncü bir durumda, blokların şekli üçgen şekilli bloklara dönüştürülmüş ve daha sonra simülasyon örneğine 60 KN yük uygulanmış ve 60.59 KN'de kırılmıştır, sensör LVDT-5-num a simülasyon yazılımı Abaqus 33.54mm yer değiştirmeyi göstermektedir. ayrıca, LVDT-4-num sensörü 35 mm yer değiştirme gösterirken, LVDT-2 ve LVDT-2, Şekil 4.24'te gösterildiği gibi 3.45 mm'yi gösterir. Ayrıca, simülasyon sonuçları ile deneysel sonuçlar karşılaştırıldığında, deneysel numunedeki basınç dayanımı 55 Mpa ve LVDT-exp (2,4,5 ve 6) sensörünün sonucu (5.65 mm, 30.9 mm) olduğu için veriler oldukça farklıydı. , 30,38 mm ve 4,61 mm), tam satır exp ile bir Şekil 4.24'te gösterildiği gibidir.

4.6. Result of changing steel plate thickness

Başlangıç uygulamalarında blokların şekli kare şekilli bloklara dönüştürülmüş ve daha sonra simülasyon örneğine 60 KN yük uygulanmış ve 59.1KN'de kırılmıştır, sensör LVDT-5-num a simülasyon yazılımı Abaqus 33.54mm yer değiştirmeyi göstermektedir. Buna ek olarak LVDT-4-num sensörü 35 mm yer değiştirme gösterirken, LVDT-2 ve LVDT-2, Şekil 4.18'de gösterildiği gibi 3.35 mm'yi gösterir. Ayrıca, simülasyon sonuçları ile deneysel sonuçlar karşılaştırıldığında, deneysel numunedeki basınç dayanımı 55 Mpa

ve LVDT-exp (2,4,5 ve 6) sensörünün sonucu (5.65 mm, 30.9 mm) olduğu için veriler oldukça farklıydı. 30,38 mm ve 4,61 mm) sırasıyla tam satır exp ile bir Şekil 4.18'de gösterildiği gibidir.

4.6.1. Değişen çelik levha kalınlığının sonucu (1 mm)

İlk durumlarda çelik levha kalınlığı (1 mm) olarak değiştirildi, bu nedenle bu durumda 54.09 KN daha fazla yük oldu. Bununla beraber, Abaqus simülasyon yazılımı LVDT-5-num sensörü 29.36 mm yer değiştirmeyi gösterirken, sensör LVDT-4-num 30.66 mm yer değiştirmeyi ve LVDT-2 ve LVDT-6 2.75 mm yer değiştirmeyi gösterir, Şekil 4.26'da gösterilmektedir. Bu bağlamda simülasyon sonuçları ile deneysel sonuçlar karşılaştırıldığında, veriler oldukça farklı elde edilmiştir. Nitekim deneysel numunedeki basınç dayanımı 55Mpa ve sensör LVDT-exp (2,4,5 ve 6) sonucu (5.65 mm, 30.9 mm, Sırasıyla 30,38 mm ve 4,61 mm), tam satır exp ile bir Şekil 4.24'te gösterildiği gibi tespit edilmiştir.

4.6.2. Değişen çelik levha kalınlığının sonucu (2mm)

Diğer bir modelleme olarak, çelik levha kalınlığı (2mm) olarak değişti, bu nedenle bu durum için daha büyük yük 59.1 KN idi. Bu bakımdan Abaqus simülasyon yazılımı LVDT-5-num sensörü 33,54 mm yer değiştirmeyi gösterirken, LVDT-4-num sensörü 35 mm yer değiştirmeyi ve LVDT-2 ve LVDT-6, 3,35 mm yer değiştirmeyi göstermektedir. Bu durum Şekil 4.28'de gösterildiği ibidir.

4.6.3. Değişen çelik levha kalınlığının sonucu (3mm)

İkinci bir durumda, çelik levha kalınlığı (2mm) olarak değişti, bu nedenle bu durumda 54.09 KN daha büyük yük olmuştur. Bu durumla beraber Abaqus simülasyon yazılımı LVDT-5-num sensörü 29,36 mm yer değiştirmeyi gösterirken, LVDT-4-num sensörü 30,66 mm yer değiştirmeyi ve LVDT-2 ve LVDT-6 2,75 mm yer değiştirmeyi göstermiştir. Şekil 4.30'da gösterildiği gibidir. Ayrıca, simülasyon sonuçları ile deneysel sonuçlar karşılaştırıldığında, veriler oldukça farklı olarak tespit edilmiştir. Nitekim

deneysel numunedeki basınç dayanımı 55Mpa ve sensör LVDT-exp (2,4,5 ve 6) sonucu (5.65 mm, 30.9 mm, Sırasıyla 30,38 mm ve 4,61 mm), tam satır exp ile bir Şekil 4.30'da gösterildiği gibi çıkmıştır.

5. SONUÇ VE ÖNERİLER

Çalışmanın verdiği sonuç, bir bina veya inşaat yapımında termal köprü sorununun üstesinden gelmek için balkon levhasında ısı yalıtım elemanı kullanımının gerekliliğini ortaya koymaktadır. Bu çalışma kapsamında balkon levhası üzerinde eğme testlerini gerçekleştirmek için birçok simülasyon uygulanmıştır. Bu sonuçlar, numunelerin, sensörlerin analiz edilmesiyle araştırılan yer değiştirme faktörüne göre yaklaşık 60,8 KN'lik büyük bir yük tutabildiğini ortaya koymuştur. Bununla beraber balkon levha örneklerinin farklı alanları üzerinde yer değişiklikleri de gerçekleşmiştir. Bu model çalışmalarına ek olarak, bu çalışmanın bir sonucu şeklinde, minimum miktarda yüksek mukavemetli betonun verimli bir şekilde kullanılmasının, büyük yüklerle dayanmak için yeterli olduğunu ve daha az ısı kaybının meydana geldiğini ortaya koymak için bu uygulamanın bir termal bariyer görevi gördüğünü de ortaya koymuştur. Bu modelleme, balkon içeren yapı projelerinde konstrüksiyonlu balkon döşeme numunesi tasarımlının kullanılması, termal köprü sorununun en aza indirilmesine veya bu sorunun üstesinden gelinmesine yardımcı olacağı sonucuna da varılmış olmaktadır.

Simülasyon sonuçları bakımından sonuçlara odaklandığında, İzo Blok için 55MPa beton kullanımının balkonda kullanım için optimum dayanıklılık sağladığını göstermektedir. Ancak İzo Blok betonun mukavemeti yük direncini aşırı derecede yükseltmeyebilmektedir. İzo Blok'ta farklı şekillerde beton kullanılması İzo Blok'un yük direncini etkilediği de ortaya koymaktadır. Betonun üçlü şeklini kullanarak, elde edilen maksimum yük direnci maksimum mukavemeti de ortaya koymaktadır. İzo Blok sayısını artırmanın balkonun yük direncini artırdığı ancak daha fazla beton alan taşıdığı için iletkenliği arttıgı için dezavantajlı konuma geçtiği de bu çalışma sonucunda teyit edilmiştir. Bu bağlamda termal iletkenlik ve yapısal direnç göz önüne alındığında üç İzo Blok kullanılması en verimli seçim olarak karşımıza çıkmaktadır. Elimizdeki bu araştırma, özel bir balkon levhası numune konfigürasyonunun ve yapısının termal köprü üzerindeki etkilerine ve bunun nasıl azaltılacağına vurgu yapmaktadır.

Çalışmanın bulguları, çalışmanın belli bir başarıya ivmelemini ortaya koymaktadır. Buna rağmen gelecekteki araştırmalar için bazı simülasyonlar ve parametrelerin bilimsel olarak sunulması, daha sonraki çalışmalar için önerilmektedir.

Gelecekte araştırma yapacaklar için bazı öneriler öne çıkmaktadır. Bu bağlamda farklı termal köprü kalınlıklarının kullanılarak termal köprüler üzerinde ultra yüksek dayanımlı betona sahip iki İzo Bloğun kullanılması ve olası sonuçları değerlendirilmeye uygundur. Bununla beraber bir yapı uygulamasında diğer parametrelerin etkisinin araştırılmasını ve termal iletkenliği araştırmak için yazılım ve modelin kullanımını içerik olarak kapsayabilmektedir. Diğer bir yaklaşım olarak kullanılacak yapı malzemelerinin çevre faktörleri üzerindeki etkileri de analiz edilmeye değer görülmüştür.

Appendix 1. Bending test results

	Load	LVDT2-num	LVDT4-num	LVDT5-num	LVDT6-num
0	0	0	0	0	0
22310	22.31	0.372695	4.78394	4.56101	0.372695
23834.8	23.8348	0.451024	5.6813	5.42091	0.451024
24982.5	24.9825	0.490767	6.16919	5.88772	0.490767
25629.3	25.6293	0.51626	6.48828	6.19324	0.51626
25946.4	25.9464	0.539795	6.73253	6.4276	0.539795
26309.5	26.3095	0.578438	7.06607	6.74786	0.578438
27483.7	27.4837	0.642266	7.58661	7.2471	0.642267
28661.7	28.6617	0.681142	7.9818	7.62519	0.681142
31314.1	31.3141	0.751671	8.85978	8.46459	0.751671
33849.3	33.8493	0.815797	9.70273	9.27064	0.815797
35965.2	35.9652	0.873667	10.3933	9.93082	0.873668
38049.1	38.0491	0.932276	11.18	10.6829	0.932276
39892.9	39.8929	0.992096	11.9384	11.4084	0.992096
41352.6	41.3526	1.03738	12.5626	12.0059	1.03738
42410.5	42.4105	1.07697	13.1048	12.5248	1.07697
43540.7	43.5407	1.1404	13.8661	13.2538	1.1404
44929.3	44.9293	1.20672	14.6265	13.9818	1.20672
46061.4	46.0614	1.28732	15.4777	14.798	1.28732
46798	46.798	1.32994	15.9711	15.2706	1.32995
48817	48.817	1.4989	17.8111	17.0352	1.4989
50173.6	50.1736	1.64532	19.4021	18.5612	1.64532
51171.9	51.1719	1.75817	20.5224	19.6364	1.75817
52249.9	52.2499	1.89958	21.8399	20.9015	1.89958
52995	52.995	1.99126	22.6875	21.7154	1.99126
53829.3	53.8293	2.08642	23.6189	22.6092	2.08645
54117.2	54.1172	2.12013	23.9585	22.935	2.12023
54542.2	54.5422	2.16767	24.4715	23.4269	2.16761
55096.1	55.0961	2.22842	25.1545	24.0815	2.22841
55706.7	55.7067	2.29512	25.9698	24.8621	2.29513
56363.8	56.3638	2.36807	26.7619	25.6218	2.36807
59107.2	59.1072	3.35591	35	33.5437	3.35591



CURRICULUM VITAE

She finished secondary and high school education from Erbil / Iraq in 2005. The same year had accepted in Erbil technical University / Erbil, Faculty of Engineering, Department of Civil Engineering. In 2019 she had graduated from Civil Engineering Department. In September 2019, she started his postgraduate study in the Civil Engineering Department, Institute of Natural and Applied Sciences at Van Yüzüncü Yıl University – VAN.





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