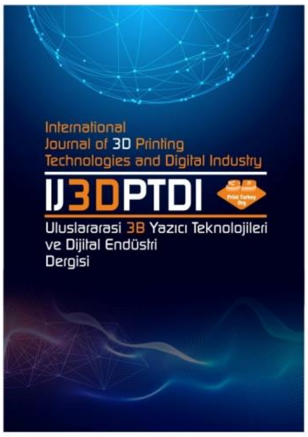

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DETERMINATION OF BUILDINGS WITH TORSIONAL IRREGULARITY BY ARTIFICIAL INTELLIGENCE METHODS

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ABSTRACT

Reinforced Concrete (RC) frame buildings with shear wall are widely used in severe seismic zones. Shear walls are bearing system elements that provide the greatest resistance against horizontal force under the effect of the earthquake, limit displacements, and prevent torsions. A reinforced concrete shear wall is one of the most critical structural members in buildings, in terms of carrying lateral loads. However, irregular layouts cause torsional irregularity in buildings. For this purpose, different shear wall frame reinforced concrete building models are designed. The model buildings have a regular formwork plan. The shear wall layout has different variations in each plan. These structure plans were mainly classified into two classes according to their torsional irregularities as structures with torsional irregularities and Structures with non-torsional irregularities. Artificial intelligence (AI) has revolutionized industries such as healthcare, agriculture, transportation, and education, as well as a variety of structural engineering problems. Artificial intelligence is transforming decision-making easier and reshaping building design processes to be smarter and automated. Artificial intelligence technology of learning from an existing knowledge base is used to automate various civil engineering applications such as compressive strength estimation of concrete, project pre-cost and duration, structural health monitoring, crack detection, and more. In this study, it is aimed to determine the structures with torsional irregularity using artificial intelligence methods. Besides, the study is expected to introduce and demonstrate the capability of Artificial intelligence-based frameworks for future relevant studies within structural engineering applications and irregularities.

Keywords: Artificial Intelligence, Shear Walls, Reinforced Concrete Shear Wall, Torsional Irregularities.

1. INTRODUCTION

Today, societies' desire to seek a healthier, safer, and more productive world is increasing exponentially with the developing world. The desire of societies to seek a healthier, safer, and the more productive world s increasing exponentially with the developing world. Depending on this situation, engineering services demand increases. Especially nowadays, Engineering services leave important traces in our lives by blending with technology [1].

Computers and computer systems are an indispensable part of life. Many devices, from household goods to mobile phones, work with computer systems. This situation has made the interaction between the human brain and devices inevitable.

Considering all these, the interest in computer systems and artificial intelligence and the studies on the subject are increasing day by day.

Especially with humanoid robots, artificial intelligence and artificial neural networks studies have accelerated. In civil engineering, artificial intelligence methods have been widely used in the fields of civil engineering applications. Artificial intelligence provides valuable alternatives for solving civil engineering problems efficiently. The developments in computer technique have also attracted the attention of structural engineers who do theoretical and practical studies, and methods known as artificial intelligence; It has been used in studies such as reaching an effective solution among many design parameters, choosing a carrier system, controlling standards, the vulnerability of structures under earthquake risk, determination and classification of soil properties [2].

Nowadays, many buildings are designed with multiple irregularities for serviceability, aesthetic or economic reasons. Thus, it can be stated that the concept of the regular building is an idealization, and in practice, many structures are unsymmetrical and irregular [3].

Rapid population growth, tall buildings, and irregular buildings have greatly increased the potential for human exposure to multiple hazards [4].

Many academicians have studied the shear wall effect in reinforced concrete structures and concluded that shear walls positively affect the behavior of the building during earthquakes. In this context, shear walls contribute to building safety for reinforced concrete structures. However, the irregular placement of the shear walls in the plan causes torsional irregularity in the structures. Torsional irregularity is one of the most important factors that cause serious damage (even collapse) to the structures [5].

Improper applications that create irregularities in structures cause a more complex structural system behavior. As a result of various load patterns on the structures, unexpected effects can be observed in irregular structures, such as extra shearing, torsion, etc. Structural irregularities significantly reduce the seismic performance of buildings [6]. The behavior of the structure under torsion is given in Figure 1.

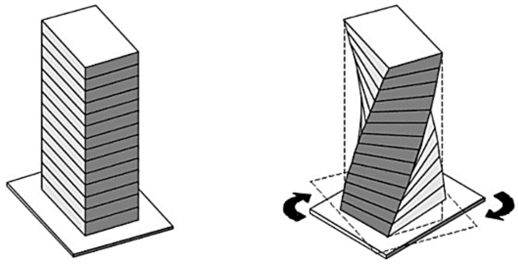

Figure 1. Behavior of structure under torsion [7].

Torsional irregularity, which is accepted in most seismic design codes, varies depending on a number of factors such as plan geometry, dimensions and positions of structural members, and number of floors [5]. In the Turkish Earthquake Codes (TEC 2018) [8], torsional irregularity is defined as one of the irregularities in the plan. This irregularity arises when the ratio of the maximum relative displacement of each story in the earthquake direction to the average relative displacement of the same floor is greater than 1.2. This situation is illustrated in Figure 2, Eq. It is obtained by the expression in 1. one.

$$\eta_{bi} = {(\Delta_i)_{max}}/{(\Delta_i)_{avg.}} > 1.2 \qquad (1)$$

In story drift calculation, if there is a torsional irregularity with ±5% accidental eccentricity in any foor of the structure, a ±5% accidental eccentricity value should be increased, multiplied with the Di coefcient, provided that $1.2 < \eta_{bi} \leq 2$ given in Eq. 2 for both earthquake directions (TEC 2018) [8].

$$D_i = \left({\eta_{bi}}/{1.2}\right)^2 \qquad (2)$$

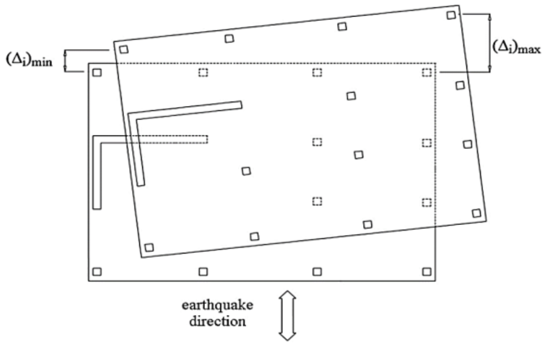

Figure 2. Torsional irregularity, Turkish Earthquake Codes (TEC 2018) [8].

Extra care and attention must be paid to ensure that torsional effects do not prevent the ductile behavior of the structure. In the event of an earthquake, building rotates about its center of rigidity. The growth of the eccentricity between the center of mass and the center of rigidity causes the torsional effects to increase which causes displacements and drifts in the buildings [9].

There are two main reasons for the occurrence of torsion effects. the first is the lack of symmetry of the structural system because of the uneven distribution in the plan of the stiffness, mass, or strength. The asymmetrical configuration of the building results in the combination of the translational and rotational vibration modes of the structures. The second is the asynchronous movement of the foundation of the building caused by the characteristics of the seismic excitation. As a result, torsional vibrations can also occur in symmetrical buildings [10].

In recent years, deep learning algorithms have gained great importance in systems based on image processing technology. Especially deep convolutional neural network (CNN) is currently the most popular method [11]. Deep learning algorithms have been used in face recognition [12], biometric recognition [13], image classification [14] or object detection [15], and many similar practical applications [16-19].

VGGNet is a deep convolutional neural network developed by researchers from Oxford University Visual Geometry Group and Google DeepMind [20]. There are six network models with depths ranging from 11 to 19 layers. Among them, the two deepest sets of 16 and 19 layers are best for classification and geolocation tasks [21]. The whole structure has 5 convolutions, the convolution kernel size is 3x3. The stride length is 1 and the padding is 1. After each convolution, a maximum pooling layer is monitored. The size of the pooling layer is 2x2 and the step length is 2. After the last max-pooling layer, three fully connected layers are connected to integrate the features in the image feature map. The last layer of the network is the Softmax layer, which is used for final classification and normalization.

Compared with the traditional convolutional neural network, the most obvious improvement of VGGNet is to reduce the size of the convolution kernel and pool kernel, increase the number of convolution layers, and adopt a way according to the pre-trained data to initialize parameters [22]. Unlike the traditional convolutional neural network, using 2×2 small pool kernels provides more detailed information capture, and using the maximum pooling method introduces larger local information variance.

In the last four decades, numerous researchers have conducted extensive studies to investigate the torsional response of buildings. Despite this effort, no study classifies structures as risky or not, in terms of torsional irregularity using artificial intelligence methods.

In this study, the effects of shear walls on the torsional irregularity and the importance of the correct placement of the shear walls in the plan are emphasized. To examine the behavioral changes caused by the different placement of the shear walls in the plan, 400 different floor plan models were created and it was aimed to evaluate whether the plan models would create torsional irregularity or not by using Artificial intelligence methods.

2. MATERIAL AND METHOD

In the study, deep learning was used to control torsional irregularity caused by shear wall in buildings. A data set was created by taking approximately 400 images from the 2D images of the shear wall drawings placed regularly and irregularly. 80% of the created data set is divided into training, 10% testing, and 10% validation data. Then, the data set was trained with the VGGNet-16 model. The diagram of the deep learning model is shown in Figure 3 below

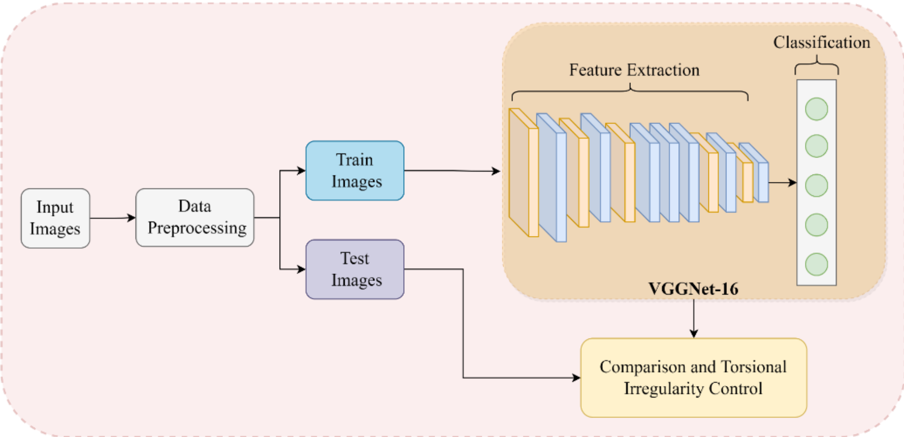

Figure 3. VGGNet-16 Deep Learning Diagram.

Building images with and without the possibility of torsional irregularity originating from shear wall can be seen in Figure 4 below. The images shown in the figure were randomly selected from about 400 images belonging to two different classes used as the data set.

Figure 4. Sample dataset images of 2 different classes with and without torsional irregularity.

4. RESULTS AND DISCUSSION

The Loss and accuracy graph obtained as a result of deep learning is shown in Figure 5. The values obtained as a result of the training are given in Table 1.

Table 1. Training Results of VGGNet-16 Deep Learning Model.

	Precision	*Recall*	*FI-SCORE*
Non-Torsional Irregularity	0.94	0.94	0.94
Torsional Irregularity	0.94	0.94	0.94
Accuracy			94%

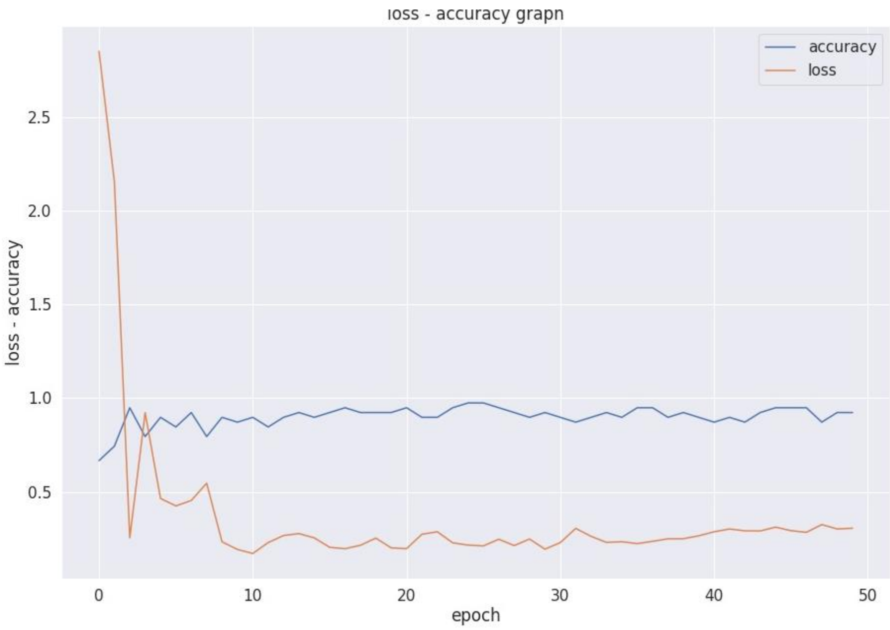

Figure 5. Loss and accuracy graph.

As a result of the study, it was observed that the proposed deep learning architecture was 94% successful in torsional irregularity control. It is seen as an area open to research and development by increasing the complexity of the related subject with different variables and applying different deep learning models going forward.

5. CONCLUSIONS AND FUTURE WORK

All engineering structures and buildings have an important place in the economy and play a vital role in facilitating daily life for the world population. When buildings are incorrectly designed, they are subject to premature damage and are nearing the end of their service life. If the buildings are damaged under static and dynamic loads, it is costly to repair or strengthen these structures. Therefore, in order to increase the safety and structural integrity of these structures and to reduce the possible financial and life losses caused by their failure, it is necessary to determine that the structures do not have irregularities. The irregular arrangement of the shear walls used in the buildings in the plan creates a torsional irregularity in the buildings. One of the most damaging effects of irregular structures under earthquake loads is the torsion effect.

Recent developments in artificial intelligence (AI), in particular deep learning (DL), have been significantly advancing civil engineering applications. This research paper presented the significance of Artificial Intelligence methods for civil engineering applications. It has been found that this study meets the expected goal of classifying the input images on the building that give information about torsional irregularity. This study paves the way for automation of torsional irregularity characterization in building plans where only shear wall layout data from building plan images is required.

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