Behaviour of T layout structures with and without dilatation

J Sunaryati, Nidiasari and M Z Efendi
Civil Engineering Department, Andalas University, Indonesia

Corresponding author: jati@eng.unand.ac.id

Abstract. Horizontal asymmetries in buildings can cause the building to experience torsion when receiving lateral loads where the earthquake load is one of the lateral loads. In this study, analyses of structures that have horizontal asymmetry is carried out in the form of structures with a T layout. To eliminate the torsional effect on buildings due to earthquake loads, the structures are dilated so that the structures are analyzed into two buildings with the purpose of they become two symmetrical buildings (Models 2 and 3). Time history response analysis was performed to assess whether there was an impact on the structural elements around the dilatation. The most significant result in model 1 is when the first mode of the structure rotates. Meanwhile, after being given dilatation, the two separate structures have moved in translation in mode 1 and 2. The deviation between floors in each model does not exceed the allowable deviation between floors. The building experienced pounding at 21.63 seconds, but this can be overcome by the separation of the structure (dilatation). The planned dilation distance is 70 mm.

1. Introduction
Earthquake load is a force with a lateral direction to the structure. This load can cause a torsional effect on the building if the shape of the building is asymmetrical [1]. Asymmetrical conditions in the building will cause the building's center of gravity not to be in the center of the building, causing a torsional effect when given a horizontal force [2]. If an asymmetric building receives a continuous earthquake load for a long period, the resulting torsional effect will be greater so that the deformation causes the building to become inelastic. So one that can be used to reduce the effectiveness of asymmetrical buildings is to separate structural elements that have different shapes or orientations, known as building dilation [3].

The use of dilation between two adjoining buildings causes each building to work as a single, separate system. The width of this dilation has been regulated in Indonesian earthquake regulations as well as various international regulations. The distance of dilation must be taken into account. If the dilation distance is narrow, then if it is exposed to a shift due to vertical or horizontal forces it will cause many problems, such as damage to the dilatation itself, leaks that are difficult to repair, even damage in other parts due to the impact of the two buildings.

For structures with a T-shaped building layout, the dilation is designed in an area that makes the structure divided into two symmetrical and regular structures. In Figure 1, the building is divided in half by dilation (represented by the dashed red line), into an upper side (Model 3) and a lower side (Model 2). It is necessary to plan carefully the dilatation distance so that the two structures do not strike. In this research, various structural conditions due to earthquake loads were studied if the T-shaped structure was given and not dilated.
2. Methodology

2.1. Description of the buildings
There are three models analyzed in this study, namely Model 1, Model 2 and Model 3. Model 1 is a full T layout building which is not dilated (Figures 1). After being dilated, the buildings in Model 1 split into Model 2 (Figures 2) and Model 3 (Figures 3). Column, beam and plate dimensions in Model 1 are also used in Models 2 and 3.

![Figure 1. Layout Model 1](image1)

![Figure 2. Layout Model 2](image2)

![Figure 3. Layout Model 3](image3)

2.2. Material properties of test specimens
The data of the analyzed structure is reinforced concrete structure with 8 story, the function of the building as an office building, located in the city of Padang, the quality of the concrete is 35 MPa, the quality of steel reinforcement is 390 MPa for the main reinforcement and 320 MPa for stirrups. The data of the analyzed structure is reinforced concrete structure with 8 story, the function of the building as an office building, located in the city of Padang, the quality of the concrete is 35 MPa, the quality of steel reinforcement is 390 MPa for the main reinforcement and 320 MPa for stirrups. Beam dimensions (30x60) cm, (25x50) cm, (20x40) cm. Column dimensions 1st floor (70x70) cm, 2nd and 3rd floor (65x65) cm, 4th and 5th floor (60x60) cm, 6th and 7th floor (50x50) cm, roof floor (40x40) cm.
2.3. Structural modeling
The three building models are modeled with SAP2000 [6] as illustrated in Figures 4 - 6 below.

![Figure 4. Modeling of Model 1](image)

![Figure 5. Modeling of Model 2](image)

![Figure 6. Modeling of Model 3](image)

2.4. Padang city time history
The earthquake load used in this research is the time history earthquake load of Padang city, which is obtained from the earthquake records of Padang in 2009. The recorded data is in the form of ground acceleration versus time as shown in Figure 7 below.
3. Results and discussion

3.1. Dynamic characteristic

The fundamental period T is a very important property in the structural design process, especially in earthquake resistant structures. The period of structural vibration will determine the magnitude of the earthquake load that will be applied in structural design. The natural period of vibration of a structure is a natural property of a structure dependent on mass and stiffness that vibrates freely in the absence of external forces.

Based on the Indonesian National Standard SNI 1726-2012 article 7.8.2 [4], the fundamental structure period (T), in the direction correspond must be obtained using the structural properties and deformation characteristics of the element in structural analysis. The period of Model 1 was 1.49 seconds, Model 2 was 1.39 seconds and Model 3 was 1.49 seconds. And both models in mode 2 and mode 3 structure experience translation in the x direction and the y direction, but for Model 1, move in the direction of rotation on first mode

3.2. Mass participation

The mass participation analysis in Model 1 has reached 96.86% for the horizontal axis of the building and 96.86% for the vertical axis of the building. In Model 2 the mass participation is 96.73% for the horizontal axis of the structure and 96.81% for the vertical axis of the structure. In Model 3, mass participation has reached 97.37% for the horizontal axis of the structure and 97.25% for the vertical axis of the structure. Based on SNI 1726-2012 article 7.9.1, it is stated that the number of various vibrations reviewed in the summation of responses must produce a mass participation of at least 90%. From the results obtained, the three models analyzed have exceeded 90% of that required by SNI 1726: 2012.

3.3. Horizontal irregularity

3.3.1. Torque irregularity

Table 10 in SNI 1726: 2012 requires that the limit of torsion irregularity in the direction of the horizontal axis of the structure is 1.2 and in the vertical direction of the structure is 1.4. From the results of the structural analysis of the three models, it was found that the torsional irregularity of the building still met the requirements as shown in the graph in Figures 8-10 below.

3.3.2. Inner angel irregularity

From the building layout, it is found that Model 1 is a structure with an irregular inner angle because $P_y = 24$ meters where $0.15L_y = 6.3$ meters and $P_x = 12$ meters where $0.15L_x = 7.2$ meters. Models 2 and 3 do not include inner angle irregularities because both structures are symmetrical. These parameters refer to the parameters specified in FEMA 451B [7].
Figure 8. The torque irregularity of Model 1

Figure 9. The torque irregularity of Model 2

Figure 10. The torque irregularity of Model 3

3.4. Deviation between floor
From the structural analysis, it is reviewed the displacement that occurs in the structural elements around the dilatation. The difference in displacement between the two floors is the deviation between the floors. Deviation between floors of permits is regulated in SNI 1726; 2012. Deviation between floors from Model 1, Model 2 and Model 3 can be seen in Figures 11-16 below

Figure 11. Deviation between floors in x direction of Model 1

Figure 12. Deviation between floors in y direction of Model 1
3.5. Pounding on structural elements around the dilatation

Maximum displacement due to earthquake loads must be checked in the form of time history function due to Model 2 and Model 3. This check is carried out at the end points of the dilation on each floor. The maximum elastic displacement value in Model 2 occurs at 17.72 seconds while Model 3 occurs at 18.58 seconds. For this reason, the direction of motion of the two structures is checked in both conditions. From Figure 17, it can be seen that the structure of Model 2 and Model 3 of the structure moves in the same direction. From Figure 18 it can be seen that at 18.58 seconds the structures move apart from each other. At 21.63 seconds, it turns out that the two structures are moving closer together so that there is a possibility that the two structures could collide. Based on this analysis, the width of the dilation that must be given between the Model 2 and Model 3 structures is referred to. By referring to Article 7.12.3 of SNI 1726: 2012, the maximum dilation distance is 93.22 mm (Table 1). From the structural analysis, the value of maximum elastic displacement of Model 2 at 21.63 seconds is +10.231 mm, while Model 3 is -13.514 mm. Thus, it still leaves a safe space of 69.475 mm.

| Model | δ_{max} (mm) | C_d | I | δ_{MI} (mm) | δ_{MT} (mm) |
|-------|---------------|-----|---|-------------|--------------|
| Model 2 | 10.231 | 5.5 | 1 | 56.271 | 93.225 |
| Model 3 | 13.514 | 5.5 | 1 | 74.327 |

4. Conclusions

An analysis of T-layout buildings has been carried out. From the analysis, it is found that if the building is not dilated, then the building experiences an irregular inner angel. To solve this problem, the building must be divided into two symmetrical and regular structures. This separation is done by providing dilation. An analysis of the structural elements around the dilatation was carried out. From the results of the analysis, it can be concluded that by using the limit of the dilatation distance in SNI
1726: 2012 which is 93,225 mm, pounding between the two separate buildings will not occur. However, for the sake of architectural comfort, the minimum distance from the dilation is obtained by attention to the deviation when the possibility of a pounding occurs, namely at 21.63 seconds.

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Acknowledgments
Thank you to the Department of Civil Engineering, Andalas University for providing financial support for this paper. This paper was funded by the Civil Engineering Department, Andalas University in the 2020 RKAKL.