

Seismic Damage Simulation of Masonry Structure Based on CityEngine

Baitao Sun, Jikai Yu^a and Xiangzhao Chen

Key Laboratory of Earthquake Engineering and Engineering Vibration, Institute of Engineering Mechanics, China Earthquake Administration, Harbin 150080 china

^ayjk603@126.com

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Abstract. This paper use rule modeling to simulate the damage of masonry structure in the earthquake on the cityengine platform. Meanwhile this paper discussed the method that how to simulate the damage of masonry structure more actual on the city level. Compared with the existing simulation of earthquake damage, earthquake disaster simulation in CityEngine has advantages that modeling fast, high reality and can give different parts of the model related attributes. Meanwhile cityengine can use GIS data and could model in a batch. This paper provides a new method for city level earthquake disaster simulation.

1. Introduction

When the earthquake occurred, in order to rescue timely, we need to have the knowledge of the damage of earthquake disaster scene, especially the destroy of buildings, the fastest way is to make 3D scene simulation of earthquake disaster scene to guide the rescue team to rescue timely, meanwhile the three dimensional simulation of structures earthquake damage is important for the rapid assessment of earthquake economic loss.[1] By comparing the use of domestic mainstream 3d modeling software, found that the concept of CGA rule modeling which proposed in CityEngine software, is a good solution to the first problem, and this software can call the data in GIS, and cityengine can build a lot of structure very fast[4], and avoid modeling in CAD, Skechup, 3Dmax, and then imported to ARCGIS like before. It is more important that we can divide different parts of the building in CityEngine, and we can attribute each part of facade to avoid other software disadvantages, so we provide a new method to distribute different part of outside facade in the simulation of crack damage. In this paper, we use the CityEngine platform to realize the division of the component of the single masonry building and to give a new method to describe damage in the earthquake.

2. Research ideas

After the earthquake, damage index describe the damage level of a structure , and we can get the index by calculating the damage index of a building, then based on the damage index, we can get the crack distribution and calculate the building cracks distribution on each floor, each component of the facade, then the data is loaded into CityEngine and attribute to each component. the damage simulation can be made a analysis diagram as shown below:

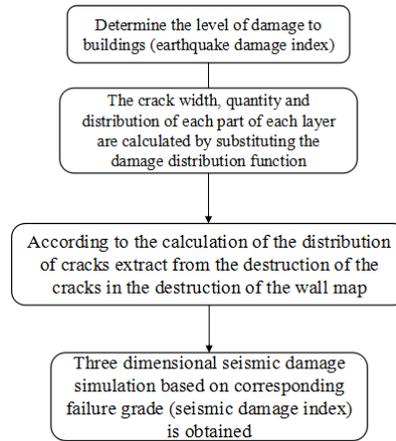


Fig.1 Block diagram of seismic damage of masonry structure

In the cityengine, each part can be replaced, can give attributes, so this paper uses the method of dividing component, when make a structure model, divide the facade based on different parts of the structure, and the facade is divided into 5 categories: the wall between window, the wall under window, the wall of corner of window, gable and other wall.

In order to make the simulation results closer to the real damage situation, this paper adopts the method that crack damage is extracted from real damage in the picture as the map of destroy wall, and we need to establish 3D seismic characteristics library, according to the site of wall, crack shape and crack grade in classification statistics for extracting convenient. the 3D seismic feature database structure as follows the:

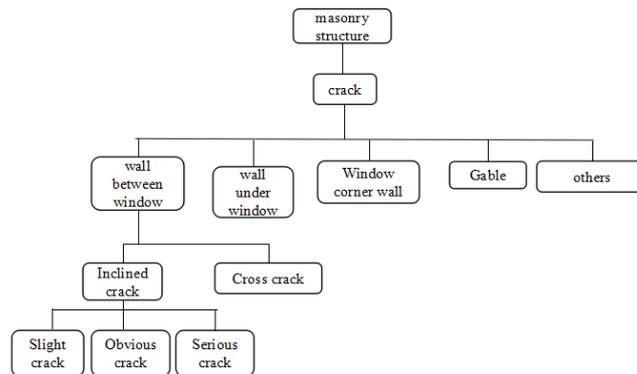


Fig.2 The establishment of 3D seismic damage feature library

3. Establish the 3D seismic characteristic database

3.1 Classification of wall

In general masonry structure of the external wall can be divided into 5 categories according to the location: the walls between windows, wall under windows, wall of window corner, gable, others, as shown in the following figure:

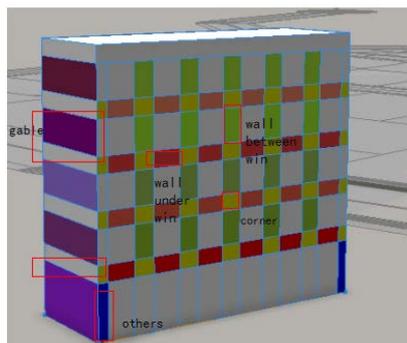


Fig.3 Classification of wall

3.2 Crack shape

According to the statistical analysis of the real earthquake damage pictures, we can find that, the crack shape is mainly divided into two types: inclined cracks and cross cracks, the destroy cause by bending will have transverse cracks. The shape of crack is affected by certain rules, which facade mainly occur inclined cracks and cross, very little wall will occur transverse cracks and vertical crack, the shape of crack which occur in the real earthquake as shown below:



Fig.4 inclined cracks and cross cracks



Fig.5 Transverse crack of exterior wall

Therefore, according to the real crack shape, we divide the seismic damage cracks into: inclined cracks and cross cracks.

3.3 Classification of cracks

Building earthquake damage level of crack width were divided by using the grading standards of cracks, 1) minor cracks: Cracks in masonry structures with width less than 1.5mm 2) medium cracks: the crack width is greater than 1.5mm, less than 3mm 3) serious crack: crack width is greater than 3.0mm[5]. In the earthquake, extension length of crack will also affect the structure severity, in rural housing in Sichuan Province earthquake damage class technical guide also describe the length of the crack 1): the length of slight crack of masonry structure is not greater than 1.5m 2) medium cracks between slight and serious fracture: 3) serious crack: crack width is greater than 1.5m. Combine the two standard, the level of cracks is divided by the two indicators which contains length and width, the crack width of parts extract from the definition of standard. In this paper, we use pixel to describe the width of cracks, and according to the percentage of the length of the wall cracks define the crack length. the classification standard of crack is shown as follows:

Table 1 Fracture classification standard

Crack level	Crack shape	Width (pixels)	Length ratio (%)
Slight crack	inclined	2	0.6
Medium crack	inclined	5	0.8
	cross	5	1
Serious crack	inclined	more than 10	1
	cross	more than 10	1

3.4 raction methods of real cracks

This paper is mainly due to the crack simulation level, we need to extract the crack shape from the damage photo layer and add a new layer with the corresponding width of the brush along the actual crack outline. Then we get the crack layer, and merge the crack layer and new wall background layer. We can get the wall cracks in the wall. This paper use white background that we can see the crack clearly.



Fig.6 real damage picture

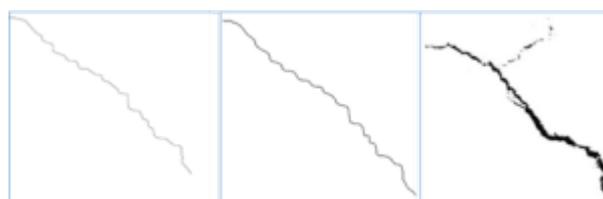


Fig.7 Crack images after extract

3.5 Establishment of earthquake damage model database

Using the simulation method of the crack, we should establish the three-dimensional seismic feature library, which is extracted from the real earthquake damage cracks according to the site of wall, to simulate three kinds of crack damage level, which is extracted from 6 pieces seismic damage pictures of cracks contain different kinds of shape and site. According to the standard to the crack damage simulation contains three grades, which have total of 180 crack images. In accordance with the characteristics of the preparation of their names, such as "cj_jiaocha_mingxian_01.png", which meaning is that the wall between windows is cross cracks, cracks obviously, picture code is 01. This definition name is convenient for the replacement work, thus we create the three-dimensional seismic damage feature library.

4. Using the rule modeling to simulate the destroy of a single masonry structure

4.1 external facade component division

According to the size of Leigu junior middle school teachers' dormitory, and in order to highlight the display of crack distribution, the model has to be simplified, so let the model have the white background, and the decoration is only the window. The basic data of building contains total building height of 18.5M, and the window height is 2m, length 2m, and have 1.5m interval, and the length of side wall is 0.75m, the gable height of each floor is 3m, every floor has 1m from the bottom of each floor, the remaining gable interval is 0.5m

Building modeling code:

Lot-->

```
extrude(18.5)
```

```
Building
```

```
Building-->
```

```
comp(f){top : Roof|front : front|back : back|left : sidewall|right : sidewall}
```

```
front-->
```

```
split(y) { 1.5 : f0cxw| 2 : f0|1.5 : f1cxw|2 : f1|1.5 : f2cxw|2 : f2|1.5 : f3cxw|2 : f3|1.5 : f4cxw|2 : f4|1.5 : roofwall }
```

```
back-->
```

```
f0cxw-->
```

```
split(x) { 0.75 : f0bqx|{ 2 : f0cx| 1.5 : f0cxjx }*2 : f0cx|0.75 : f0bqx }
```

The segmentation of the different components use different colors to distinguish, as shown in the following figure:

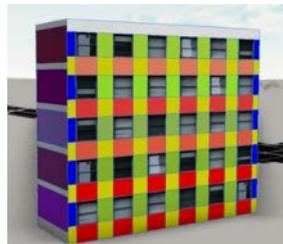


Fig.8 Component segmentation result color display

4.2 Simulation of seismic damage

Through the statistics of the real earthquake damage, we can get the fracture distribution rule[6], summed up that when the damage index range of $[d_1, d_2]$. Take the three grades of crack distribution proportion in different floors of different parts of the rules into the rule file, you can simulate the building damage when the damage index is d . Then we get the median of three corresponding damage index distribution simulation results.

Crack distribution simulation code

```
f0cx -->
```

```
case intensity >= 0.1 && intensity < 0.3 : 8% : cxqingwei
```

```
else: wanhao
```

```

case intensity >= 0.3 && intensity < 0.55 : 61% : cxqingwei 25%: cxmingxian 0%: cxyanzhong
else: wanhao
case intensity >= 0.55 && intensity < 0.85: 11% : cxqingwei 28%: cxmingxian 61%: cxyanzhong
else: wanhao
else: wanhao

```

4.3 Crack shape classification

At this time, the damage state of a component has been known, and the shape of the crack must be known. According to the statistics, the shape of the crack is also regular

```

Crack shape distribution code
cxmingxian-->
60% : cxmingxian_xie_ else :cxmingxian_jiaocha
cxmingxian_xie_-->
setupProjection(0, scope.xy, '1, '1)
projectUV(0)
texture(cx_mingxian_xie)
cxmingxian_jiaocha-->
setupProjection(0, scope.xy, '1, '1)
projectUV(0)
texture(cx_mingxian_jiaocha)

```

Thus, the 3D building earthquake disaster simulation has been done, and the three grade earthquake are shown as below. From the result , destruction of buildings facade components can be seen all, and because it has architectural properties variability, like height, we can change the number of attributes of the building , so that we can quickly get other earthquake damage of masonry structure. The simulation results are shown in the following figure:



Fig.9 Slight damage



Fig.10 Amplification of slight damage



Fig.11 Medium damage



Fig.12 Serious damage

5. Summary and Outlook

The 3D model established in this paper simulate the seismic damage of masonry structure, can be directly applied to other plots in CityEngine, and the CityEngine can directly connect the ArcGis data according to the attribute information of each block, such as floor, unit number. We can achieve the model rapidly. In this paper, for us to see the distribution of cracks more clearly, so we use white walls, the actual application of the white wall can be replaced by the actual background, then the model will greatly enhance the authenticity, as shown in the following figure:

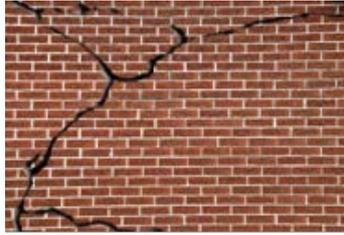


Fig.13 Simulation of real wall crack

This paper introduces the simulation of 3D seismic damage, and provides an efficient and fast method to simulate earthquake disaster of building damage. we just need to get the building crack distribution changes with the damage index, then we get the percentage of crack distribution, and the method can quickly and intuitively display the simulation.

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References

- [1] Baitao Sun. Realization of 3D Simulation System for Urban Seismic Damage [J]. Earthquake Engineering and Engineering Vibration. 2010(05)
- [2] Changli Hu; Preliminary Study on Three - dimensional Model of Masonry Structure and Realization of 3D Disaster Scene[D]; Institute of Engineering Mechanics, China Earthquake Administration; 2009
- [3] Bo Han; Xinzheng Lu; Zhen Xu; Yi Li; Seismic Damage Simulation of Urban Buildings Based on High Performance GPU Computing [J]; Journal of Natural Disasters; 2012. May
- [4] Hui Zhao, Chao Liu, Yan Li, Youjie Wang. Research on 3D Modeling Technology of Buildings Based on CityEngine [J]. Mapping notification. 2014(11)
- [5] Criteria for Seismic Destruction of Buildings (GB/T 24335-2009)[S]. General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China; China National Standardization Administration Committee
- [6] Qiang Zhou. Seismic test of masonry structure and analysis of elasto - plastic seismic response[D]. Harbin Engineering University. 2012-03-01