THE THEORETICAL ANALYSIS ON THE SEISMIC EFFECT OF GROUND FISSURES IN XIAN

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Introduction

Since 1976 the ground fissures both in the city and suburbs of Xian have been strongly developed and a lot of buildings located near by them damaged. For the last years these fissures have brought to the attentions of many scientists and architectural departments, who have done much work and a number of papers dealing with the ground fissures have been published.

But in most of the published papers, the consideration was taken only into the geological structure and the causes of the ground fissures. No one studied the effect of these fissures during strong earthquakes, which is very important for the urban planning and construction design.

In the present paper, the author studies only the seismic effect of the fissures by theoretical method and does not deal with any other problems about them.

A brief account of the analytical method

Theoretical analysis has been carried out by the two-dimensional finite element method. The theoretical basis of this method is to solve the simultaneous equations of elastic system under the effect of two-dimensional shaking:

$$[M]\{\ddot{x}\}+[C]\{\dot{x}\}+[K]\{x\}=[M](\{A_x\}x_0(t)+\{A_y\}Y_0(t))$$

where $[M]$, $[C]$, $[K]$ are the mass, damping and stiffness matrices respectively, $\{\ddot{x}\}$, $\{\dot{x}\}$ and $\{X\}$ are the acceleration, velocity and displacement of degree of freedom system respectively. $\{A_x\}$, $\{A_y\}$ are the vectors degree of freedom in horizontal and vertical course; while $X_0(t)$ and $Y_0(t)$ are the processes of the horizontal and vertical accelerations of the bed rock surface.

There are 4 principal steps in the calculation.

1. To simplify the system into elastic multi-point model, to solve the

period of vibration and mode vector after statistic analysis。

2.To input the acceleration records$X_0(t)$and $Y_0(t)$,to calculate the response of every mode.

3.To solve the general response of every degree of freedom by mode superposetion,i.e.,to calculete the time history of acceleration for every degree of freedom,which is located on the ground surface.

4.To solve the Fourier spectra,acceleration,velocity and displacement response spectra of single mass-point model。

The detailed discription of this method and its mathematical requiment is written in the reference[1]。

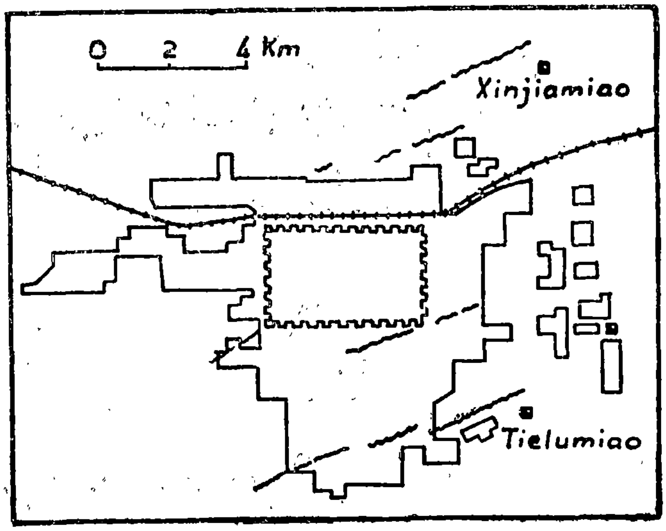
Main conditions and parameters of site soil

As we will know,it is necessary to simplify the naturel conditions before the finite element analysis.All of the ground fissures in Xian are located along some zones(Fig.1), which vary in width from 5 to10 meters [5].Within every zone there are some ground fissures which are arranged in echelon.Their depth varies from 10 to 15m.According to these conceptions we can adopt the two-dimensional model which is perpendicular to the fissure zone.The fissure zone can be simplified as a wedge with the end downwards,the depth of the peak being 20 m under the ground surface. The width of its upper roof on the ground surface is 10m,and there is an open crack in the center of the zone.The model for calculation is shown in Fig.3 and 4.

According to the seismic geologic conceptions of the surrounging area of Xian,[4,2,1]there is no reason to consider the ground fissures as the causetive structure[2,3,6].So,we,dealing with the fissure zone as a geologic unit,analyzed only its dynamic response during strong earthquake.The ground shaking was inputed from the bottom-face,the fixed boundary of the model.

The main parameters of the site soil were determined in situ(see Fig1). And the simplified results are illustrated in Table 1.As we can see from this fissures,the strength of the site soil in the southen part is relatively stronger than that in the northen part of Xian.We cited two typical sections ---Xinjiamiao and Tielumiao sections,which represente the conditions of northen and southen part of Xian. In calculation,the section across the fissure zone was simplified and the average parameters of the site soil were adopted.

The depth of the model bottom was determined by experiment and 50m under the ground surface was adopted。



ground fissure zone　　location of the model section

Fig. 1　Location of the ground fissures in Xian(after[5])

图1　西安地裂缝分布示意图（振据[5]简化）

Both the El Centro in 1940, in U.S.A and the Wenxian accelerograms in 1976 in Gansu provence, China, were selected as the input seismic motions. The records were slightly remoulded as thus, the maximum acceleration was about 0.15g, which is in correspondence with the intensity of 8 degree.

Table 1　The parameters of site soil in xian(a) for xinjiamiap, (b) for Tielumiuo

表1　西安场地土的参数(1)辛家庙剖面(2)铁炉庙剖面

Depth (M)	unit weight (T/M³)	Poisson ratio	Elastic modul (kg/CM²)
10	1.65	0.25	1500
20	1.75	0.30	4000
30	1.80	0.35	3000
50	1.85	0.40	7000
0—20 (Fissur zone)	1.55	0.35	800

(a)

Depth (M)	unit weight (T/M³)	Poisson ratio	Elastic modul (kg/CM²)
10	1.70	0.25	2500
20	1.80	0.30	3800
30	1.85	0.35	5000
50	1.90	0.40	7500
0—20 (Fissur zone)	1.60	0.35	1000

(b)

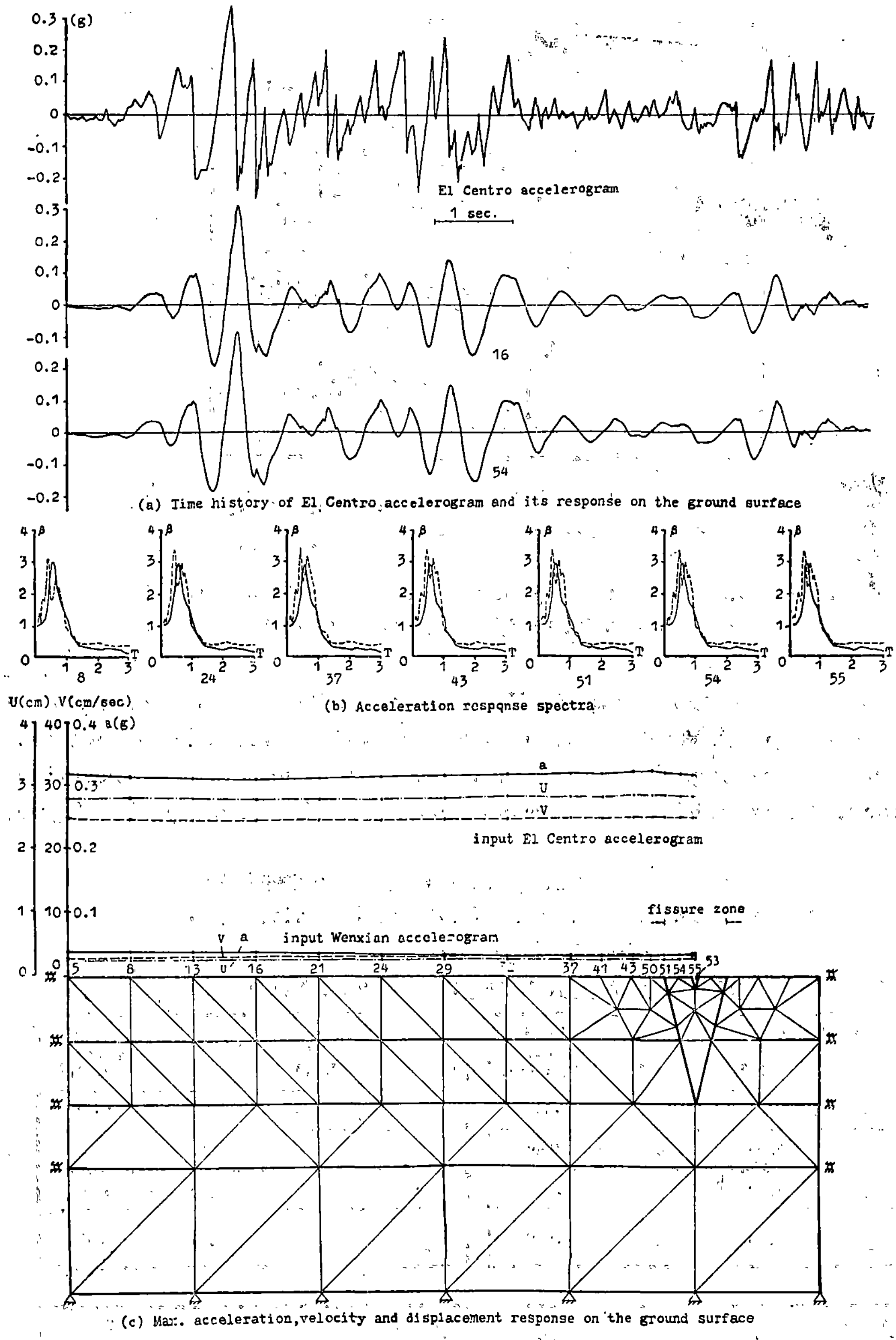
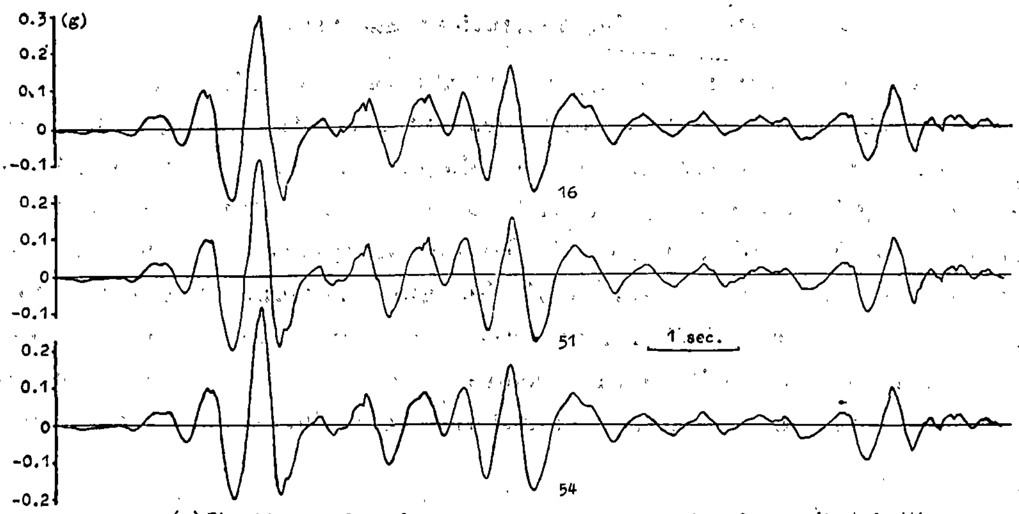
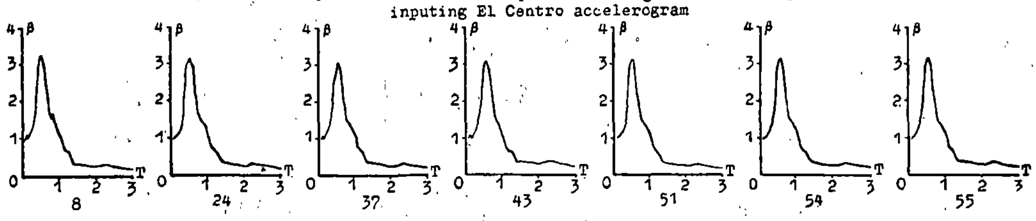


图 2 铁炉庙剖面的计算结果

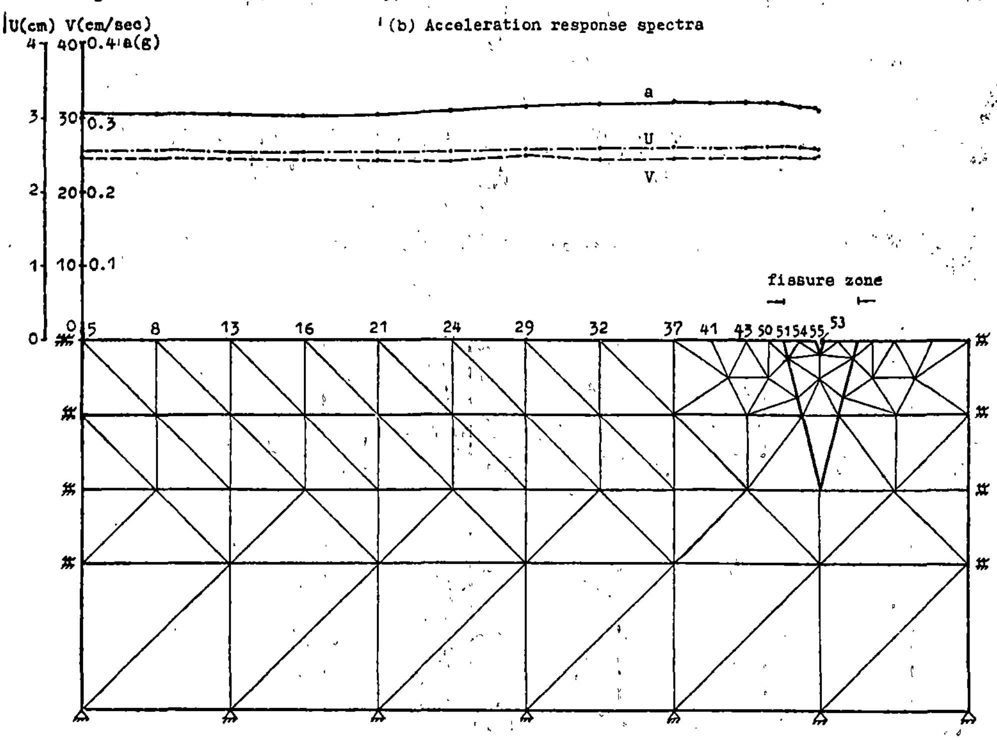
Fig. 2 Result of analysis for Tielumiao model



(a) Time history of acceleration response on the ground surface predicated with inputing El Centro accelerogram



(b) Acceleration response spectra



(c) Max. acceleration, velocity and displacement response on the ground surface

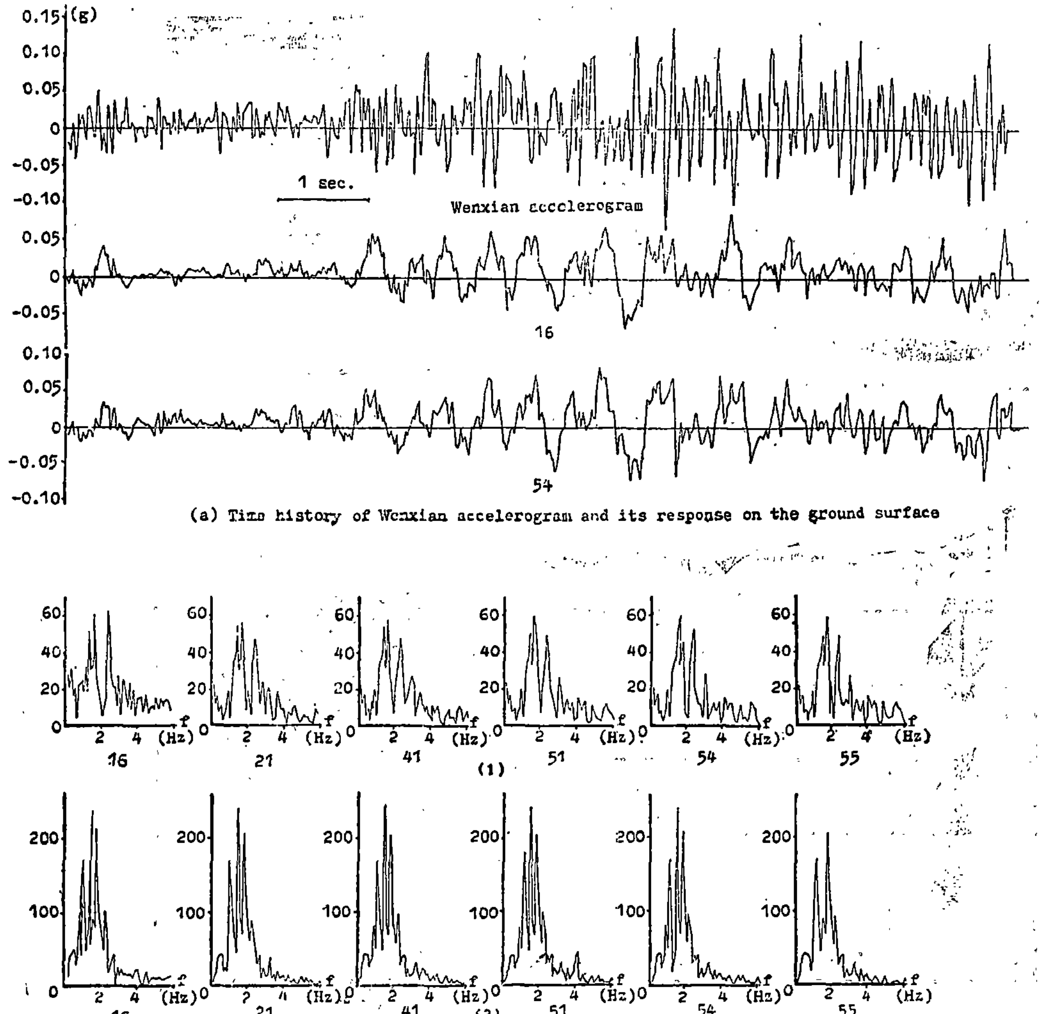
图3　辛家庙剖面的计算结果

Fig. 3　Result of analysis for Xinjiamiao model

Results of the theoretical analysis

The results of theoretical analysis are shown in Fig. 3—5.

In general, the ground fissure zone does not exert the apparent influence on the characteristics of ground motion during strong earthquake. As we can see from Fig 2—4, both within and out fhe fissure zone the maximum acceleration, velocity and displacement are not obviously different fron each other regardless of the characters of the input motions. In Fourier spectra, the frequence characteristics are also not remarkable different, only with the exception that within the fissure zone about 1 Hz vibration frequency is more conspicuous than it is out this zone. The acceleration respon-



(a) Time history of Wenxian accelerogram and its response on the ground surface

(b) Fourier spectra of acceleration response on the ground surface predicated with inputing Wenxian (1) and El Centro (2) accelerogram

图4 辛家庙剖面的计算结果(续)

Fig. 4 Result of analysis for Xinjiamiao model(continued) se spectra do not appear essential different,except that the peak of spectra of the fissure zone is just slightly higher than that is out of it.

The above mentioned results are easily explained.In the regional scale, the ground fissure zone is only a minor geologic element.So,despite of its great influence on the constructions,its width and depth are,after all, very limited.Such a minor geologic element cannot cause singnificant effect on the characteristics of ground motion during the strong earthuqake.

But it should be considered that the site soil of the fissure zone is ease to be effected with permanent deformation during strong earthquake, because the site soil is looser.Therefore,along the fissure zone ground failure may be caused by shaking.It is estimated that degrees of ground failure must be of great difference within and out of the fissure zone.In spite of obvious difference in the characteristics of ground motion,the ground failure can also make the damage heavier in the fissure zone.

It can be seen from this,that during the strong earthquake in the surrounding area the damage is not heavier just for the existence of the fissure zone.Onlg along the zone the damage may become heavier on account of ground failure.Therefore,in making the plan against shaking it is unnecessary to widen the zone protecting against earthquakes out of the common fortified zone.

Conclusion

1.The ground fissure zone in Xian does not exert apparent effect on the characteristics of ground motion during the strong earthquakes.Differences of earthquake damage in and out of the ground fissure zone will be caused mainly by ground failure instead of ground motion.

2.It is clear that the area where the earthquake damage will be heavier is limited within the fissure zone.So,it isn't necessary to delimit aspecial belt to protect against the strong earthquake out of the fortified zone.

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西安市地裂缝地震效应的理论分析

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本文采用有限元方法对西安市地裂缝的地震效应进行了分析，其目的在于探索强震时地裂缝对地面运动的影响。所用方法的理论基础是在双向地震动的作用下求解多质点体系的强迫振动方程组：

$$[M]\{\ddot{X}\}+[C]\{\dot{X}\}+[K]\{X\}=[M](\{A_x\}\ddot{X}_0(t)+\{A_y\}\ddot{Y}_0(t))。$$

式中〔M〕、〔C〕、〔K〕分别为体系的质量、阻尼、刚度矩阵，$\{\ddot{x}\}$、$\{\dot{x}\}$、$\{x\}$分别为体系自由度的加速度、速度、位移向量，$\{A_x\}$、$\{A_y\}$为水平和垂直方向的自由度向量，$\ddot{x}_0(t)$、$\ddot{Y}_0(t)$为水平及垂直方向上的基岩强震加速度时程向量。

分析时根据西安市地裂缝的具体情况，做了如下简化：

1.裂缝不作为发震构造，即强震时裂缝不是弹性波的发源地。强震是通过铰结支座输入进来的。

2.裂缝带在模型上是一向下尖灭的楔体，楔体顶面宽10米，楔体深20米，中间有一宽1米、深2米的裂口。整个模型的土质是层状的，各层土的主要参数在现场测定。裂缝带楔体的参数不易取得，按经验强度取周围原土的一半左右。

3.模型厚度为50米，输入地震为El Centro 和文县强震记录，输入时将最大加速度值调整为150gal。

计算结果表明，西安裂缝带在强震时对地面运动没有显著的影响，如地裂缝带内外的各种反映强震运动特征的指标几乎都没有什么差异。因为地裂缝带从区域上看毕竟是个很小的地质单元体，这样小的规模尚不足以对强震地面运动产生显著的影响。

但是，地裂缝带在强震时的永久地形变却是值得注意的。从这一点上看，裂缝带内外地基失效程度必定有很大的差别，从而使裂缝上的震害加重。

可见，在强震时，除地裂缝带本身因地基失效使震害加重而外，裂缝基本不对强震地面运动规律产生影响。所以在进行防震规划时，不必在常规的设防带之外再加宽防震地带。