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Research Article

Seismic response analysis of overhead pipe under multi point input

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Abstract: Ground motion has a strong randomness because of the limitation of the number of strong earthquake records and mathematical difficulties. In general, by the method of establishing stochastic process model, one can study the influence of spatial correlation of ground motion on seismic response of structures. However, more researches focus on the random process model of acceleration. According to the acceleration stochastic process model, the frequency domain model and time domain model are selected to study the composition of ground motion at each point of the ground pipeline, and further consider spatial correlation of ground motion to give the influence of traveling wave effect, coherence effect and local site effect on the ground pipeline. The results show that it may be unsafe without consideration of the spatial coherence of seismic ground motions, and different coherence function models lead to different results. It is also suggested that the spatial coherence of seismic ground motions should be considered, and the coherence function models should be chosen cautiously.
Keywords: frequency-domain model; time-domain model; ground motion simulation; spatial correlation.

INTRODUCTION

There are some papers to study the seismic response of random earthquake to the pipelines under the ground [1-3]. However, there are few results on whether or not the coherency of the space can be neglected when we consider the seismic response of the pipelines over ground. In the paper, we study the problem. By the random model of the acceleration, we give the response of the effects of the travel wave, coherency and local field respectively to the pipelines over ground, through considering the coherency of the space and the compose of multi points earthquake.

We choose the Du-Chen’s power spectral model[4] and the Hao’s method of the earthquake compose[5], and use the Adina software to the strain of the earthquake wave as it propagates along with the axis direction under the multi point supporting. Furthermore, we give the corresponding analysis and results for the consideration in seismic design.

THE CHOICE OF THE RELATED PARAMETERS OF EARTHQUAKE WAVE

Frequency domain model of acceleration process of seismic response

We take the following Chen-Du model [4] as the power spectrum model

$$S(\omega)=\frac{1}{1+(D\omega)^2}\cdot\frac{\omega^4}{(\omega_0^2+\omega^2)^2}\cdot\frac{1+4\zeta_g^2(\omega/\omega_g)^2}{[1-(\omega/\omega_g)^2]^2+4\zeta_g^2(\omega/\omega_g)^2}S_0 \quad (1)$$

where $S(\omega)$ denots the power spectral density function; D the spectral parameter charactering the property of the ground rock, ω_0 :the corner frequency of low frequency; ζ_g site dumping ratio; ω_g site dominant frequency and S_0 denotes the factor of spectral intensity. In the paper, we assume that seismic fortification intensity is seven, and the value of basic earthquake acceleration is 0.10g. The field is taken as the third category, the design earthquake is the first class, and the character period of the field is 0.45s. According to the references[6,7], the parameters of self-power spectral model are taken as in table 1.

Table 1 the parameter selection of since the power spectral density function

$D(s)$	ω_0	ω_g	ζ_g	$S_0(m^2\cdot s^{-3})$
0.03	1.83	13.96	0.8	0.003345713

By the results in Qu[8], we assume that the thickness of soil layer is invariant, and then we have $\Delta S_0 = -0.0124\Delta x_0$. When we consider the change of S_0 with x, we call this local effect, otherwise, ignoring the local effect.

Coherency function model

Since the model of Harichandran and Vanmarcke (HV, for simplicity)[9] and QWW model[8] are suitable for the third and forth class fields, we take these two models to study the effects of coherency function model to seismic response of the pipeline over ground.

(1) HV model

$$\gamma_{k,l}(\omega,d) = A\exp[-\frac{2d}{\alpha\phi(\omega)}(1-A+\alpha A)] + (1-A)\exp[-\frac{2d}{\phi(\omega)}(1-A+\alpha A)] \quad (2)$$

$$\phi(\omega) = K[1+(\omega/k_0)^b]^{-1/2} \quad (3)$$

where A, α, K, k_0, b are regression coefficients. By reference [9], $A = 0.736$, $\alpha = 0.147$, $K = 5210$, $k_0 = 6.85$ rad/s, $b = 2.78$.

(2)QWW model

$$\gamma_{kl}(\omega,d) = \exp[-a(\omega)d^{b(\omega)}] \quad (4)$$

$$a(\omega) = a_1\omega^2 + a_2, b(\omega) = b_1\omega^2 + b_2$$

where a_1, a_2, b_1, b_2 are regression coefficients. By reference [8], $a_1 = 0.00001678$, $a_2 = 0.001219$, $b_1 = -0.0055$, $b_2 = 0.7674$.

The time domain model of acceleration process of earthquake

We take the following model [10], see figure 1

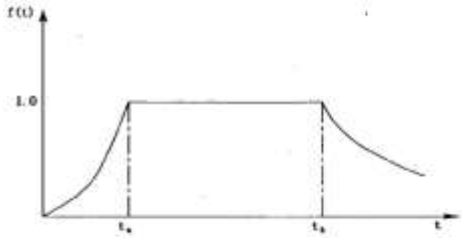

Figure 1 piece-wise function graph

$$f(t) = \begin{cases} t^2/t_a^2 & t \le t_a \\ 1 & t_a \le t \le t_b \\ \exp\{-a(t-t_b)\} & t \ge t_b \end{cases} \quad (5)$$

where, t_a, t_b and a are the parameters of controlling the time and decay, and the continuance time of the main shock is $T = t_b - t_a$. By the reference [7], we take $t_a = 1.2s, t_b = 10.2s$.

By the frequency model, coherency model and time domain model form the matrix of the cross power spectrum. According to the Hao's method [5] ,by using Matlab software to write the program to get the time travel curves of the acceleration of every supporting places in the pipeline over ground.

Analysis of example

By using ADINA software, we build the finite element model of 32m length supporting pipeline, and take a support by every 6m, and hence there are 6 supports. The pipe is parted into16 units in ring direction, and divide a unit per 0.2m in axis direction. The support is simulated by using spring unit, the vertical stiffness is taken as 1e7, the horizon stiffness is infinity, the supports and pipe are linked by pipe clamps, the constraints of bottom of pipe supports and the pipe ends are the same, because this article adopted large mass method impose earthquake excitation in y direction on the pipe, so the y direction constraints are release, see the figure 2.

Fig-2: The finite element model of supporting pipe

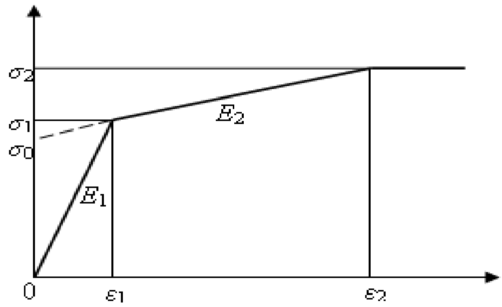

Fig-3: Three line model for stress-strain relations

In our example, we take the pipe of API5LX60, the stress-strain relation is taken as the model in figure 3, where, σ_0 =4.62e8Pa, σ_1 =4.65e8Pa, ε_1 =0.0024, E_1 =2.1e11Pa; σ_2 =5.16e8Pa, ε_2 =0.04, E_2 =1.356e9Pa;

We impose earthquake excitation in y direction on the pipe, the maximum axial strain value and the maximum value of y direction displacement of 11 points including six points which pipe are connected with each support and five points at the bottom of the cross section of the pipe are extracted. Under different conditions, the maximum axial strain value and the maximum displacement value in y direction of the 11 points of the pipeline are shown in figure 4 to figure 5.

Table 2 the maximum axial strain value and the maximum displacement value in y direction (unit: pa)

cases	maximum strain	Maximum displacement
HV model: ignore local effect	0.046	0.249
HV model: consider local effect	0.027	0.297
QWW model: ignore local effect	0.036	0.343
QWW model: consider local effect	0.022	0.398
completely coherent: ignore local effect	0.005	0.387
completely coherent: consider local effect	0.009	0.232

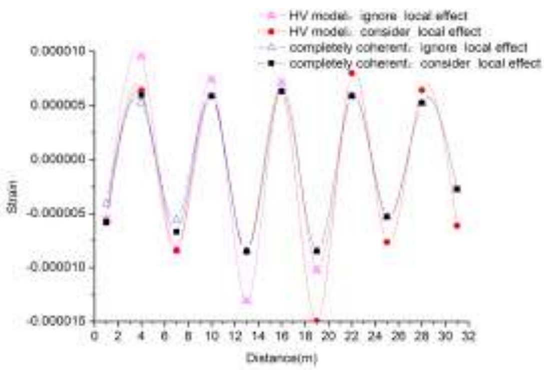

Fig-4a: strain value comparison chart

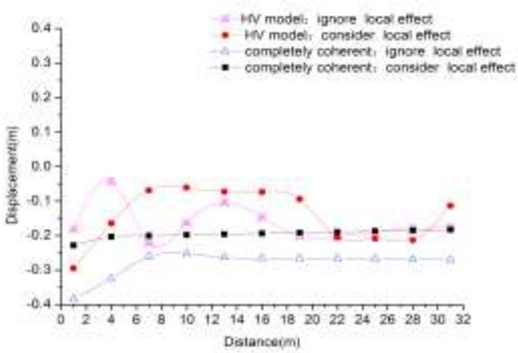

Fig-4a: displacement value comparison chart

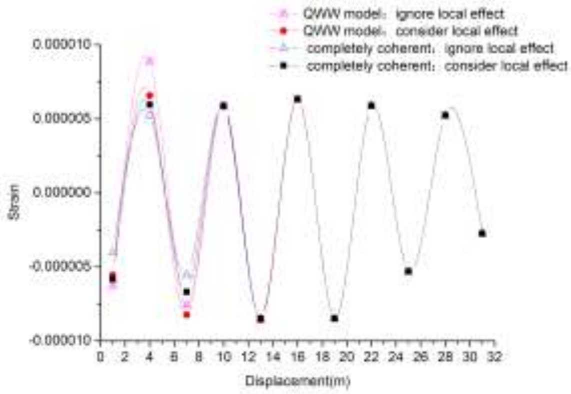

Fig-5a: strain value comparison chart

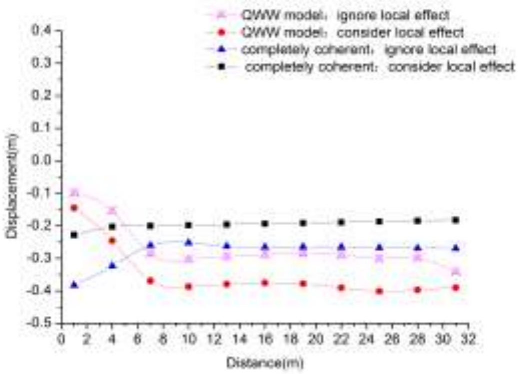

Fig- 5a: displacement value comparison chart

In HV model, maximum axial strain value considering the effect of local site is 41.3% smaller than that ignoring the effect of local site, and maximum displacement value in y direction is 19.3% bigger than that. In QWW model, maximum axial strain value considering the effect of local site is 38.9% smaller than that ignoring the effect of local site and maximum displacement value in y direction is 16% bigger than that. Completely coherent conditions, maximum axial strain value that considering the effect of local site is 80% bigger than that of ignoring the local site effect, maximum displacement in y direction is 40.1% smaller than that ignoring the effect of local site.

In order to analysis the response of travel wave effect to inner force of the pipe unit, we compute three input types including the uniform excitation of unidirectional earthquake, apparent wave velocity 50m/s and 200m/s. We take the El-centro earthquake wave with the acceleration peak value 341.7cm/s^2, and assume that the angle between the earthquake wave traveling direction and the axis is zero, that is, these two directions are parallel. We impose earthquake excitation in y direction on the pipe, the results are given in the table 3, figures 6.

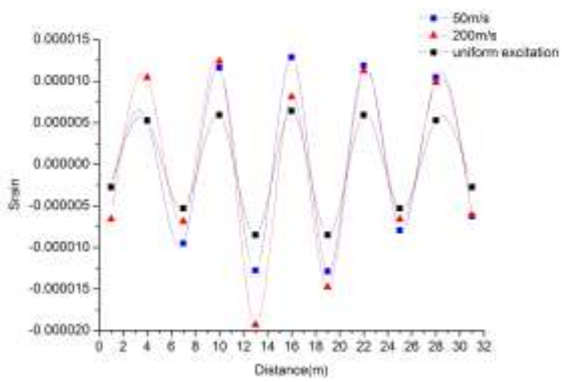

Fig-6a: strain value comparison chart

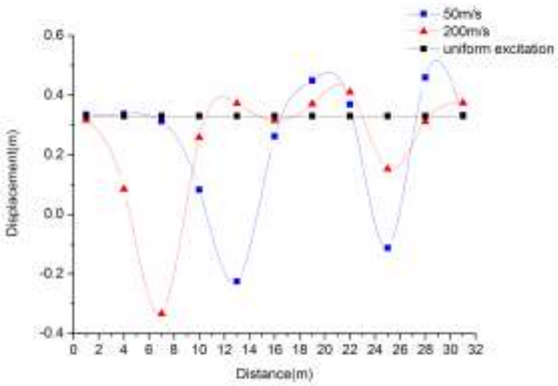

Fig-6b: displacement value comparison chart

Table 3 the maximum axial strain value and the maximum displacement value in y direction in three types of input

Input types	50m/s	200m/s	Uniform excitation
maximum axial strain value	0.160	0.161	2.494e-5
maximum displacement value in y direction	0.45	0.42	0.33

CONCLUSION

The results show that different coherence function models lead to different results, whether considering local site effect on seismic response of the pipeline also have differences. Hence it may be unsafe without consideration of the spatial coherence of seismic ground motions. It is also suggested that in practical computation we should consider the spatial coherence of seismic ground motions and choose the coherence function models which is closed to the field conditions.

From the analysis for the figures 3 and 6, we know that when the apparent wave velocity is taken as 50m/s and 200m/s, the strain extreme and the displacement extreme increase under the traveling wave effect, and hence the effect of the traveling wave must be considered for long pipelines.

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