Comparisons of Travelling-Wave Method and Difference Method for Calculating Rotational Components

Chang Chen, Yun Wang, Li-Xia Sun, Dong-Qing Li

Multi-Wave Multi-Component Group, China University of Geosciences, Beijing

MAIN POINT: Indirectly calculating the rotational components with the translational components.

A Travelling-Wave Method

- Newmark (Newmark,1969) gave the basic idea of Travelling-Wave Method.
- Wang Junjie (王君杰等.,1991) estimated the rotational components of ground motion by Travelling-Wave Method, and proposed the formulas for calculating the three rotational components:

$$\begin{cases} r_1(t) = \frac{1}{C_a} u_3(t) \sin\theta \\ r_2(t) = \frac{1}{C_a} u_3(t) \cos\theta \\ r_3(t) = \frac{1}{2} \cdot \frac{1}{C_a} [u_2(t) \cos\theta - u_1(t) \sin\theta] \end{cases}$$

u_1, u_2 and u_3 are translational movements along X, Y and Z axes respectively, r_1, r_2 and r_3 are rotational movements around X, Y and Z axes respectively, Ca is the apparent wave velocity.

We firstly establish a horizontal layered isotropic homogeneous model (Fig. 1) and carry out elastic finite difference（Sun et al., 2018） simulation to compare the difference between the rotational components simulated theoretically and calculated by the Travelling-Wave Method. The normalized rotational accelerations are shown in Fig. 2.

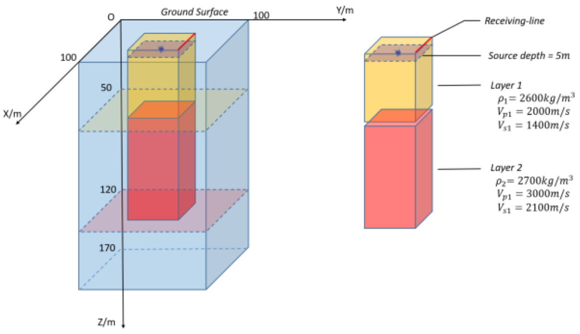

Fig1. Horizontal Layered Isotropic Homogeneous Medium

Model Size: 40m×40m× 120m
Source Type: expansion source
Wavelet Dominant Frequency: 120Hz
Grid Spacing: 1m
Sampling Interval: $dt = 0.0001s$
Recording Time: $t_{max} = 0.1s$
Boundary: Splitting Perfectly Matched Layer (SPML)

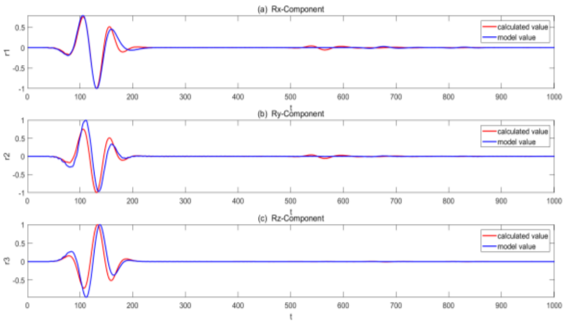

Fig2.Comparison Diagram of Normalized Rotational Acceleration Components

It can be seen that

- The calculated value is in good agreement with the synthetic value in the first arrival time, amplitude and phase.
- The calculated value of the rotational component is smaller than the measured value, and the rotational component calculated decays faster than the measured one.

B Two-point Difference Method & Comparing

The two-point difference method requires dense stations to record seismic translational components. Before and after deformation, the difference between the translational records of the two stations in the vertical direction, divided by the linear distance of the two stations in the horizontal direction, can be used as the seismic r_x or r_y rotation component with the approximate location of the stations.

$$r = \frac{\Delta u_B - \Delta u_A}{L_{AB}}$$

We process the measured six-component seismic data (Lin et al.,2008) by Two-point Difference Method. The comparing diagrams between the measured values and the calculated values by the two methods are shown in figure 3.

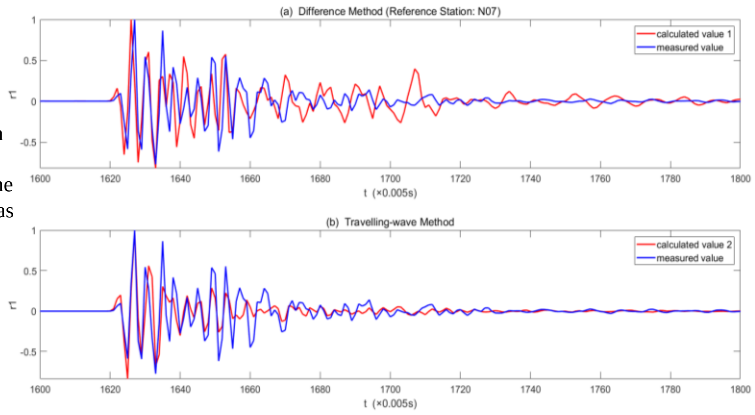

Fig3.Comparison of Rx-component of Normalized Rotational Acceleration Record

(a)Difference Method (Reference Station:N07);(b)Travelling-Wave Method

It can be seen that

- Travelling-Wave Method has higher accuracy than the Two-point Difference Method which relies on dense station array.

Reference

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Contact Information Chen Chang *MWMC Group, China University of Geosciences, Beijing*
E-mail:chch6108@163.com