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Benchmark Tests for Strong Ground Motion Simulations (Part 2)

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We have been conducting a series of benchmark tests of the strong motion simulation methods for three years since 2009. We chose the three most popular methods for this purpose: the theoretical methods (the wavenumber integration method, the discrete wavenumber method, and the thin-element method), the stochastic Green function method, and the numerical methods (the finite difference method and the finite element method). We have carried out two steps of the simple benchmark tests in 2009; one is a point source and the other is extended sources in homogeneous and two-layered structures. For the benchmark tests of the theoretical methods, the stochastic Green function method, and the numerical methods, five, six, and six groups of researchers/engineers, respectively, were participated in, by using their own methods/codes.

Table 1　The three benchmark tests in 2009.

理論的手法 (Theoretical Methods)

モデル名	ステップ	震源	地盤	Q値	観測点(km)	振動数(Hz)
T11	1	点(d=2 km)	1層	無	2,6,10,30,50,100	0～20
T12	1	点(d=2 km)	2層	無	2,6,10,30,50,100	0～20
T13	1	点(d=2 km)	2層	有	2,6,10,30,50,100	0～20
T14	1	点(d=20 km)	2層	無	2,6,10,30,50,100	0～20
T21	2	横ずれ断層	2層	無	±2,±6,±10,±30,±50,±100	0～5
T22	2	逆断層	2層	無	±2,±6,±10,±30,±50,±100	0～5

統計的グリーン関数法 (Stochastic Green Function Methods)

モデル名	ステップ	震源	地盤	Q値	観測点(km)	振動数(Hz)	乱数	断層破壊
S10	1	点(d=2 km)	1層	無	0,2,6,10	1～20	指定	—
S11-1～3	1	点(d=2 km)	1層	無	0,2,6,10	1～20	3ケース	—
S12-1～3	1	点(d=2 km)	2層	無	0,2,6,10	1～20	3ケース	—
S13-1～3	1	点(d=2 km)	2層	有	0,2,6,10	1～20	3ケース	—
S21-1～3	2	横ずれ断層	2層	無	0,±2,±6,±10	1～20	3ケース	一様
S22-1～3	2	逆断層	2層	無	0,±2,±6,±10	1～20	3ケース	一様
S23-1～3	2	横ずれ断層	2層	無	0,±2,±6,±10	1～20	3ケース	ランダム

数値解析手法 (Numerical Methods)

モデル名	ステップ	震源	地盤	Q値	観測点(km)	振動数(Hz)
N11	1	点(d=2 km)	1層	無	-10～+10(21点)	0～5
N12	1	点(d=2 km)	2層	無	-10～+10(21点)	0～5
N13	1	点(d=2 km)	2層	有	-10～+10(21点)	0～5
N21	2	横ずれ断層	2層	無	-10～+10(21点)	0～5
N22	2	逆断層	2層	無	-10～+10(21点)	0～5

We have obtained the following conclusions.

Theoretical methods: All the results show good agreements in the assigned frequency range (0 - 20 Hz). However, the results for no-damping media show slight differences at very high frequencies, because some groups used very high-Q values, whereas the other group used the Phinney method. The results for damping media show large differences, especially in the surface wave at very far stations. This is because the most of groups used the quality factors by the complex parts of the medium velocities, whereas one group used the factors not only in the complex parts, but also in the real parts, in order to satisfy the causality condition in the waveforms.

The stochastic Green function methods: all the results showed good agreements, because we used the most fundamental method, which was the point source by Boore (1983) + the waveform integration method by Irikura (1986). However, we found slight differences in the Fourier amplitudes, because some groups used iteration schemes to fit the omega-squared model, which the other groups did not used. In addition, one group used a large geometrical damping to consider the effects of the close distance between the source and the station, while the other groups did not use. As for the extended sources, we confirmed that the introduction of the random rupture times at the sub-faults were effective to avoid the artificial predominant frequencies, which caused by the regular intervals of the rupture times. We also found the serious sags in the Fourier amplitudes in the middle frequency range (around 1 Hz), as compared with the omega-squared model, which have to be improved in the next step.

Numerical methods: Since we used the very simple flat-layer models, all the results show good agreements. However, we find slight differences in arrival times and amplitudes in later phases, because of the differences in the mesh sizes, the locations of the sources and the stations, the medium properties at the boundary between the layers, and the boundary conditions of the whole domains. As the same as the theoretical methods, we found large differences in the damping models, because of the difference of the introductions of the quality factors.

Please check the following web site for more details.
http://kouzou.cc.kogakuin.ac.jp/benchmark/index.htm
In 2010, we will carry out the similar bench mark test by considering more complicated models including basin models.

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