Platform of Input Motion Selection for Taiwan (INMOST)

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Abstract

In order to address the key issue of how to select and modify recorded input motions when executing time-history analysis, this study develops a platform for input motion selection for Taiwan, or INMOST. Specific features of INMOST are: (1) meeting the requirements of Taiwan seismic design specifications; (2) generic applications for wider local sites in Taiwan (including Taipei Basin sites); (3) an interactive website with a graphical user interface; (4) provision of suitable seismic records and complete seismic information. INMOST not only succeeds in providing a useful reference for generating horizontal input motions for time-history analysis, but also has reliable practical applications in seismic analysis and design.

Keywords: ground motion selection, time-history analysis, seismic design, INMOST

Introduction and Conception

In recent decades, rapid progress has been made in earthquake engineering, which has led to new and more efficient structural systems, greatly improved quality and quantity of seismic data recordings, significantly improved performance in hardware and software, and more detailed requirements for seismic design regulations. Response history analysis using seismic time series has therefore gradually become the mainstream approach for evaluating the seismic behavior of structures.

Compared with the simple methods of response spectrum analysis and nonlinear static pushover analysis, the advantages of detailed time-history analysis are as follows. First, the structural response over time during and after the application of a real earthquake load can be fully obtained. Second, the higher mode effects and inelastic redistribution can be specifically predicted. Third, since seismic records preserve the properties of ground motions, the structural response not only directly reflects the three primary characteristics of a seismic excitation, *i.e.*, amplitude, frequency content, and duration, but also evaluates structural response uncertainties by various load paths.

However, the most practical issues of time-history analysis are how to select and modify recorded input motions from a huge amount of ground-motion data for satisfying the requirements of a seismic design code. In this context, the National Center for Research on Earthquake Engineering (NCREE) developed a platform for input motion selection for Taiwan, or INMOST (http://seaport.ncree.org/inmost). The main objectives of INMOST are (1) to facilitate local application, (2) to provide a user-friendly interface, and (3) to promote time-history analysis. The strategies of creating INMOST are (1) using Taiwan's ground-motion data and seismic design specifications, (2) supporting wider local sites and broader structural periods, and (3) designing an easy-to-use website.

Platform Development

The first stage in platform development was establishing the Taiwan Recorded Ground-Motion Database for Structural Response-History Analysis for integrating the selected seismic records that correspond to the level of a design basis earthquake in Taiwan (Liu *et al.*, 2021). Next, INMOST was developed as an intuitive and interactive website based on the above database.

The database at the back-end of INMOST is based on Taiwan seismic design specifications and contains nearly 100,000 local seismic records from 1991 to 2018. Ten datasets are grouped in this database, including seven general sites and three Taipei Basin sites. Each dataset includes thirty selected ground-motion records based on a target design spectrum that reflects one of

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the representative site characterizations in Taiwan. These selected ground motions are sorted according to goodness-of-fit of spectral shape within a specific range of periods. All parameters of the seismic source, the strong-motion station, ground motion, and ranking are listed in the metafile of each dataset. These support the powerful display and application functions at the front-end of the INMOST website.

Platform Navigation

The structure of INMOST is a one-page-website (Figure 1), so users can have an excellent experience in terms of visual effects, operation efficiency, and data acquisition. In the layout of the webpage, the right side is the welcome area and the feedback entry; the middle is the main operation area for selecting input motions; and the left side is the navigation area for the seven function tabs, which are: (1) About INMOST, (2) Selection Criteria, (3) Results Map, (4) Results Table, (5) Response Spectra, (6) Results Export, and (7) References. The contents and features of each function tab are described below.

Figure 1. INMOST webpage header.

About INMOST

The initial screen of INMOST (Figure 2) adopts the input overlay mode, and the content includes an introduction to the platform, a disclaimer, and two necessary inputs for users to provide basic information (service unit and professional title) and to agree to website usage rules. Through About INMOST, it is possible to review the development basis, service features, and usage principles on the initial screen.

Figure 2. INMOST initial screen.

Selection Criteria

There are two basic principles for the input motion of time-history analysis in the Taiwan seismic design specifications (CPAMI, 2011), Section 3.6.1 for a seismic structure, Section 9.3.7 for an isolated structure, and Section 10.4.1 for a damped structure) as follows: (1) the input motion must be consistent with magnitudes and fault distances as they control the target design spectrum and (2) the input motion must have a similar spectral shape to the target design spectrum in a specific period range regarding the fundamental period of the structure. In addition, owing to the different requirements of individual analysis projects, such as two- or three-dimensional analysis and average or maximum structural response, the input motion has other project-specific requirements to suit the local circumstances.

Therefore, the criteria for input motion selection provided by INMOST (Figure 3) meet three basic requirements: site-specific, structure-specific, and project-specific. Selection Criteria has two areas for parameter settings, Target Spectrum and Input Motion Conditions. The former has two simple options, selection of general sites or Taipei Basin sites; the latter has five items for selecting the structure-specific requirements (period range, limit of the lowest spectral value) and project-specific requirements (component of ground motion, number of records, limited number of records from one earthquake event).

Considering the practical applications, INMOST has presets for several criteria. For the target design spectra of the three Taipei Basin seismic micro-zonations, a corner period for spectral acceleration (S_a) being proportional to T^{-1} and T^{-2} is given as 4.0 s with reference to a recent study (Jean *et al.*, 2020), and the selected ground motions are focused on both the Chi-Chi (1999) and 331 (2002) earthquakes and the strong-motion stations located in the Taipei Basin area. These presets can be used to appropriately determine spectral shape similarity at long periods. For the lowest value of the scaled recorded spectrum, this criterion is for an individual input motion rather than the mean of all the input motions. For the number of selected input motions, the upper limit is 30 to facilitate the display and operability of Response Spectra.

Figure 3. INMOST Selection Criteria.

Results Map

The results of input motion selection are visualized in the three modes on INMOST: map, table, and plot, with intuitive and interactive functions that are easy to use (Figure 4).

The geographic information map provided by INMOST displays the distribution of all epicenters and strong-motion stations of the selection results. Advanced information is shown when clicking an icon for an epicenter ( ) or a strong-motion station ( ). Taking strong-motion stations as an example, details include the earthquake time, the code of the strong-motion station, the epicentral distance, the hypocentral distance, and the average shear-wave velocity (V_S) for the upper 30-m depth (V_{S30}). In addition, for a single event or all earthquake events, the epicenters and the strong-motion stations on the map can be displayed in either decluster ( ) or cluster ( ) modes. Users can interact with the map to zoom, pan, and array, then snapshot the current plot ( ).

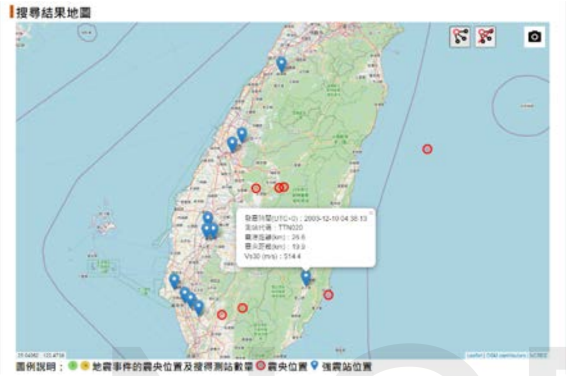

Figure 4. INMOST Results Map.

Results Table

Results Table (Figure 5) lists the parameters of the selected input motions, and its usefully interactive functions are described as follows. (1) The default sorting is according to goodness-of-fit of the spectral shape (*i.e.*, mean-squared error), but users can sort data by any parameter item. (2) The tip for a parameter appears when a cursor is positioned over this parameter item in the table header. (3) When selecting a row of ground motions, the map pans to the location of the strong-motion station. (4) The accelerograms based on original recorded data display when clicking the ACC button. (5) The show-or-hide checkboxes lead to the follow-up functions of Response Spectra and Results Export.

The tabular parameters are adequate for practical application, and can be classified into four categories:

1. ***Ranking***: This includes mean-squared error (MSE), scale factor (SF), and component of ground motion. These parameters are the critical references for selecting the applicable input motion suite and scaling the motion amplitude. When three-dimensional analysis is required, it is suggested that both horizontal ground-motion components be applied with an identical scale factor based on the geometric-mean (GM) spectrum of both horizontal components.

2. ***Seismic Source***: This includes earthquake time (UTC+0), epicentral coordinates, moment magnitude (M_w), focal depth, epicentral distance, and hypocentral distance. With these parameters, the diversity of the earthquake events can be confirmed, and the correspondence with the characteristics of the target-site controlling earthquake can also be checked.

3. ***Strong-Motion Station***: This includes the code of the strong-motion station, station coordinates, V_{S30} value, and the depth for V_S of 1.0 km/s ($Z_{1.0}$). With these parameters, the correspondence with the site conditions between target-site and strong-motion station can be checked, and the degree of basin effect or soft layer depth can also be evaluated.

4. ***Ground Motion***: This includes peak ground acceleration (PGA, A), peak ground velocity (PGV, V), strong-motion durations (5%–75% and 5%–95% Arias intensity), pulse period (T_p), and S_a at fifty specified periods. These parameters not only provide the characteristics of the ground-motion energy in terms of amplitude, frequency content, and duration, but also assist in selecting the special ground motion with long-period effects or pulse-like velocity.

搜尋結果列表 (資料總數 : 11 事件總數 : 7 測站總數 : 11)

序數	☑	群組	群組 T_0 (秒)	定比係數 (Scale Factor)	均方誤差 (MSE)	反應譜分量	原始加速度歷時圖 (ACC)	發震時間 (UTC+0)
1	☑	G4	0.7	2.36	0.0153	GM	ACC	2003-12-10 04:38:13
2	☑	G4	0.7	2.19	0.0187	GM	ACC	1999-09-20 17:47:15
3	☑	G5	0.8	2.84	0.0246	GM	ACC	1999-09-25 23:52:49
4	☑	G5	0.8	2.74	0.0262	GM	ACC	1999-09-25 23:52:49
5	☑	G5	0.8	3.28	0.0294	GM	ACC	2010-03-04 00:18:52
6	☑	G4	0.7	1.76	0.0315	GM	ACC	1999-09-20 17:47:15
7	☑	G7	1.0	2.74	0.0328	GM	ACC	2010-03-04 00:18:52
8	☑	G7	1.0	1.88	0.0345	GM	ACC	2016-02-05 19:57:26
9	☑	G4	0.7	3.78	0.0353	GM	ACC	1999-09-20 18:16:17
10	☑	G5	0.8	2.57	0.0358	GM	ACC	2016-02-05 19:57:26
11	☑	G4	0.7	2.96	0.0401	GM	ACC	2002-03-31 06:52:49

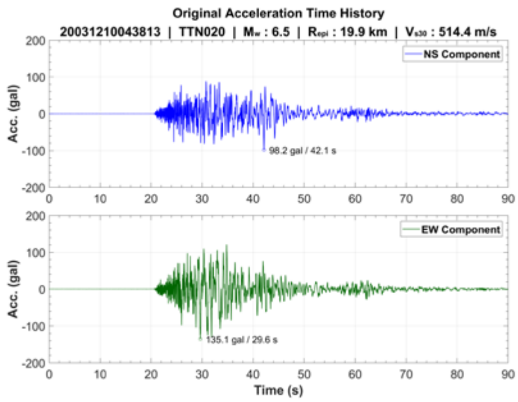

Figure 5. INMOST Results Table and accelerograms.

Response Spectra

Response Spectra (Figure 6) shows the scaled recorded spectra (colored lines), the mean of the scaled recorded spectra (black dashed line), and target spectrum (black dotted line). Users can quickly examine the suitability of the spectral shapes of the selected input motions over the period range of interest.

The interactive functions are described below. (1) The scale (arithmetic or logarithmic) and limits (minimum and maximum) of both axes of the period and S_a are easily changed. (2) The legend option allows four corner positions for its position to create the best visual effect. (3) Users can hide or show a spectrum when clicking the corresponding label in the plot legend. (4) The values of the period and S_a for a single spectrum ( ) or all spectra ( ) appear when the cursor is positioned on the plot. (5) Users can arrange any spectra style then snapshot the current plot ( ).

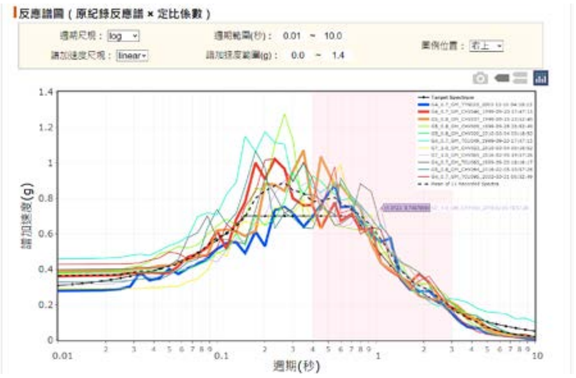

Figure 6. INMOST Response Spectra.

Results Export

All parameters displayed in the Result Table, S_a of the recorded ground motions and S_a of the target spectrum displayed on INMOST, are available to export directly as comma-separated values (CSV) files (Figure 7). Digital acceleration time-history data of earthquake events observed at the strong-motion stations in Taiwan, except for the six disastrous shocks, need to be purchased from the Central Weather Bureau. In this regard, for user convenience, INMOST provides a hyperlink to download or purchase the official earthquake records.

Figure 7. INMOST Results Export.

References

Documents and information on the development of the INMOST database, such as the Taipei Basin design response spectra with T_L, the site amplification factors following a semi-logarithmic empirical model, the procedure of ground-motion selection of the ten datasets, and the sources of pulse-like records and geological data of the strong-motion stations, are presented in full in both Technical Documents and Related Links (Figure 8).

Study reports related to INMOST will be placed in References one after another.

Figure 8. INMOST Results Export.

Summary

The intention behind developing INMOST is to solve procedural problems encountered by local engineers when selecting recorded input motions to comply with a target design basis earthquake. INMOST is a one-page website with intuitive, graphical, and interactive features. It not only succeeds in providing useful records and parametric information for generating horizontal input motions for time-history analysis, but also has reliable practical applications in seismic analysis and design.

For subsequent applications in selecting results with INMOST, users must consider the target-site characteristics such as seismic hazard (magnitude and fault distance), site conditions (*e.g.*, soft or hard layers), ground motion (*e.g.*, velocity pulses), and the followed standards, and then finally determine the appropriate earthquake records and scale factors.

The platform of Input Motion Selection for Taiwan was launched on December 30, 2021, and is available at the following URL: http://seaport.ncree.org/inmost. All are welcome to use, give feedback, and promote it.

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