Data Article

Datasets for gravelly soil liquefaction case histories

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A B S T R A C T

This data article provides summarized information on the liquefaction case histories of gravelly soil from 17 earthquakes. 234 historical cases based on the shear wave velocity test and dynamic penetration test are carefully compiled and corrected according to the data processing procedures recommended in the related research article [1]. All necessary information that helps develop the corresponding deterministic or probabilistic prediction models for gravelly soil liquefaction, including earthquake name and time, site name and its location, moment magnitude (\(M_w\)), peak ground acceleration, epicentral distance, bracketed duration, fines content, gravel content, average particle size, normalized dynamic penetration test blow count or normalized shear wave velocity, groundwater table, depth of gravelly soil deposit, total and effective overburden stress, the thickness of the impermeable capping layer, the thickness of the unsaturated zone between the groundwater table and capping layer, cyclic stress ratio for \(M_w = 7.5\), and liquefaction information, are given for the datasets.

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Specifications Table

| Subject | Geotechnical Engineering and Engineering Geology. |
|---------|-----------------------------------------------|
| Specific subject area | Geotechnical earthquake engineering, Soil dynamic, Soil liquefaction. |
| Type of data | Table and Figure. |
| How data were acquired | Literature collection, data statistics and revision; Ground motion parameters: the acceleration records of nearby strong-motion stations or the ground motion prediction equation (GPME) method when the acceleration record is not available; Partial values of average practical size, fines content, gravel content, effective overburden stress, the cyclic stress ratio for Mw = 7.5: calculated according to the data processing procedures introduced in the related research article. |
| Data format | All case histories are secondary data, and they have been screened and revised. A Microsoft Excel spreadsheet file of all data is available for public access. |
| Parameters for data collection | Earthquake name and time, site name and its location, moment magnitude (Mw), peak ground acceleration, epicentral distance, bracketed duration, fines content, gravel content, average particle size, groundwater table, depth of gravelly soil deposit, effective overburden stress, normalized dynamic penetration test blow count and normalized shear wave velocity, the thickness of the impermeable capping layer, the thickness of the unsaturated zone between the groundwater table and capping layer, cyclic stress ratio for Mw = 7.5, and liquefaction information. |
| Description of data collection | The data was collected from the literature after the screening, correcting, and repairing. |
| Data source location | Primary data sources: the literature in reference such as [2–8]. Parts of raw data could be available from the websites; Direct URL to the Wenchuan earthquake liquefaction data: http://140.112.12.21/issmge/tc304.htm?=6; Direct URL to the Chi-Chi earthquake liquefaction data: http://cecas.clemson.edu/chichi/TW-LIQ/Homepage.htm; Direct URL to the acceleration records of the strong-ground motion: https://ngawest2.berkeley.edu/, https://www.strongmotioncenter.org/index.html. |
| Data accessibility | Data is included in this article: Supplementary data in Appendix A. |
| Related research article | Jilei Hu, Data cleaning and feature selection for gravelly soil liquefaction, Soil Dynamics and Earthquake Engineering, 145, (2021), 106,711. [1] https://doi.org/10.1016/j.soildyn.2021.106711. |

Value of the Data

- The databases contain both shear wave velocity and dynamic penetration test cases from 17 earthquakes that enrich the global database of gravelly soil liquefaction case histories.
- These data are beneficial to other researchers to develop the corresponding deterministic or probabilistic prediction models for gravelly soil liquefaction and carry out further physical modeling or numerical analysis to reveal the dynamic response and liquefaction hazards of gravelly soil.
- Some errors, contradictory, and missing data have been addressed in the collected database after data cleaning.

1. Data Description

All 234 cases from 17 earthquakes summarized in Table 1 are re-compiled by the authors, which are available through the website link at the end of this article. The compiled database simultaneously contains the shear wave velocity test and dynamic penetration test cases, and
the basic information including the earthquake name, site name and location, moment magnitude ($M_w$), site name and location, peak ground acceleration (PGA), groundwater table (GWT), depth of gravelly soil deposit ($D_h$), effective overburden stresses ($\sigma'_v$), the thickness of the impermeable capping layer ($H_n$), the thickness of the unsaturated zone between the groundwater table and capping layer ($D_n$), average practical size ($D_{50}$), fines content (FC), gravel content (GC), correction of shear wave velocity ($V_s$) or correction of dynamic penetration test blow count ($N'_{120}$), and liquefaction information (liquefaction or non-liquefaction) are obtained from the literature [2–8]. Other parameters like bracketed duration of the earthquake (t) can be obtained by searching the records of the neighboring strong-motion stations, or it can be estimated using the ground motion prediction equation (GPME) method as Eq. (1) when the distance between the investigated site and the strong-motion station is larger than a threshold such as 5 Km; the epicentral distance (R) is determined in Google Earth software as shown in Fig. 2. In addition, some parameters with missing values like $\sigma'_v$ is computed assuming the soil layer above and below the GWT had the total unit weight of 17.0 and 19.5 kN/m$^3$, respectively; $D_{50}$ and GC can be calculated from each other by Eq. (3), and corrected $V_s$ and $N'_{120}$ are calculated by Eqs. (4–5) and they can be estimated from each other by Eq. (2); the cyclic stress ratio for $M_w = 7.5$ (CSR$_{L5}$) can be calculated according to Eqs. (6–8).

### 2. Experimental Design, Materials and Methods

These case histories are collected, screened, revised, and repaired, and the processing procedure is shown in Fig. 1. For earthquake parameter processing such as PGA, R, and t can be rechecked or obtained from the nearest strong-motion station (distance between the investigated site and the strong-motion station less than a threshold such as 5 Km). It is noted that if the station is located on the ground level soil layer, its motion information is valid, otherwise, its earthquake parameters are invalid when the station is located on bedrock. For instance, case No. 18 Jingxing village, CD-01 in the Wenchuan earthquake is approximately 3.3 km away from the nearest strong-motion station 51PZX located on the bedrock as shown in Fig. 2. Thus, the earthquake parameters cannot be obtained from the station record. For other cases nearby the strong-motion stations in the Wenchuan earthquake such as cases

### Table 1
Ranges of some variables in gravelly soil liquefaction databases.

| Earthquake                        | $M_w$ | CSR$_{L5}$ | GC (%) | $N'_{120}$ | No. | $V_s$ (m/s) | No. |
|-----------------------------------|-------|------------|--------|------------|-----|-------------|-----|
| 1964 Alaska earthquake            | 9.2   | 0.4–0.8    | 31–56a | 2.4–28.8   | 10  | 103–278     | 10  |
| 1906 San Francisco earthquake     | 7.9   | 0.3        | 60     | 62–11.5    | 4   | 160–203     | 4   |
| 1976 Tangshan earthquake          | 7.8   | 0.1        | 52     | 3.8        | 1   | 94          | 1   |
| 1976 Guatemala earthquake         | 7.5   | 0.1–0.2    | 19–23a | 6–0.0     | 3   | 168–206     | 3   |
| 1976 Friuli earthquake             | 6.4   | 0.1–0.4    | 21–35  | 11.0–14.6  | 4   | 200–228     | 4   |
| 1983 Borah Peak earthquake         | 6.9   | 0.1–0.4    | 34–78a | 4.9–46.1   | 44  | 123–322     | 44  |
| 1983 Nihonkai-Chubu earthquake     | 7.7   | 0.2        | 22a    | 23.6–28.5  | 2   | 256–266     | 2   |
| 1988 Armenia earthquake            | 6.8   | 0.2        | 47     | 7.4        | 1   | 153         | 1   |
| 1989 Loma Prieta earthquake        | 7.0   | 0.1        | 60     | 6.2–10.8   | 4   | 164–203     | 4   |
| 1993 Hokkaido-Nansei-Oki earthquake| 8.3   | 0.2–0.3    | 58–70  | 2.6–6.1    | 2   | 109–162     | 2   |
| 1995 Hyogo-ken-Nanbu earthquake    | 6.9   | 0.1–0.5    | 30–50  | 3.5–21     | 19  | 125–240     | 19  |
| 1999 Chi-Chi earthquake            | 7.6   | 0.1–0.8    | 4–57a  | 6.5–18.8   | 19  | 164–273     | 19  |
| 1999 Izmit-Kocaeli earthquake      | 7.4   | 0.3–0.6    | 23–56a | 9.6–30.6   | 11  | 196–315     | 11  |
| 2008 Wenchuan earthquake           | 7.9   | 0.1–0.6    | 0.4–90a| 6.7–62.1   | 81  | 160–424     | 81  |
| 2011 Tohoku earthquake             | 9.0   | 0.1–1.2    | 12–73a | 8.2–20.5   | 24  | 159–297     | 24  |
| 2016 Muinsae earthquake            | 7.8   | 0.4        | *      | 7.7–8.7    | 3   | 162–180     | 3   |
| 2016 Kaikoura earthquake           | 7.8   | 0.2        | *      | 3.2–4.1    | 2   | 123–129     | 2   |
| Gross                              | 6.4–9.2| 0.1–0.8    | 0.4–90 | 2.4–62.1   | 234 | 94–424      | 234 |

Note: a part of the value is estimated; * means unknown; No. means the number of samples.
Fig. 1. The procedure of gravelly soil liquefaction case study.

Fig. 2. Map of investigated sites and strong-motion stations in the 2008 Wenchuan earthquake in the Google Earth software.

No. 8, 22, 29, 44, 48, etc. in the database, their earthquake parameters are revised according to the acceleration records of the nearest strong-motion stations as shown in Fig. 2. However, when the acceleration record is not available, the earthquake parameters such as PGA can be obtained by the United States Geological Survey (USGS) ShakeMap (e.g., PGA values in the Wenchuan earthquake refer to the URL: https://earthquake.usgs.gov/archive/product/shakemap/usp000g650/atlas/1594174375811/download/pga.jpg), and t can be conservatively estimated.
using the following equation [9]:

$$\log t = -4.88S + 2.33M_w + 0.149 \log R$$

(1)

where PGA has units of m/s$^2$; $t$ is the bracketed duration of the earthquake with PGA greater than 50 gal; and $S = 2$, 1, and 0 for rock, firm, and soft soil sites, respectively.

Next, the critical layers in the literature are recycled in this article according to the identification criteria: 1) the stratum is liquefiable and below the groundwater table; 2) the stratum has the lowest $V_s$ or $N'_{120}$, and it should be as shallow as possible from the perspective of surface liquefaction manifestation; 3) on auxiliary identification comes from the surface ejecta which helps to indicate the liquefaction of a specific stratum. However, for those sites that did not undergo liquefaction, to expand the sample size, the critical soil layers of few non-liquefied sites in the Chi-Chi earthquake and Tohoku earthquake are not identified by the standard, but the gravely soil layer is directly selected as the representative soil layer.

In the process of collecting and verifying these historical gravelly liquefaction data, the authors discovered an interesting phenomenon, that is, the data records of the same location in different kinds of literature are not consistent as shown in Table 2. For these contradictory locations, after screening, analyzing, and repairing, the relatively reasonable or true values in bold are as shown in Table 2. For two parameters of $H_n$ and $D_n$, taking case No. 4 Nangui Village as an example, the values of $H_n$ and $D_n$ of this location were 2.0 and 2.7 m in Cao et al. [2], respectively, while their values in the same location were 4.1 and 0.7 m in Chen et al. [3], respectively. The value of $H_n$ is proposed to 4.1 m in this article after checking the raw information of the borehole [4,5]. $D_w$ of this location is 4.7 m, $D_n$ should equal 0.6 m by their relationship ($D_n = D_w - H_n$). In addition, the value of $V_s$ in this case was both 304 m/s in Cao et al. [2] and Chen et al. [3], but the average value of $V_s$ is revised to 289 m/s by calculating the raw data. Like $V_s$, $N_{120}$ also has several errors. For example, $N_{120}$ value of 3.3 per 10 cm in case No. 51 Quanshui Village was proposed by both Cao et al. [2] and Chen et al. [3]. However, this $N_{120}$ value should be revised to 9.9 by multiplying by 3.

For $D_s$, the critical layer of case No. 8 Anping village in Chen et al. [3] was between 2.8 – 3.8 m, while $D_s$ was taken 2.5 m, which is revised to 3.3 m by averaging. Besides, $D_w$ value of case No. 32 Linyan village was 6.0 m in Cao et al. [2], while it was 3.7 m in Chen et al. [3]. According to their $H_n$ value of 4.8 m and $D_n$ value of 1.2 m, $D_w$ value of 6.0 m is correct. Also, there is a contradiction between $\sigma'_v$ values of the cases No. 211 and 212 in the Avasinis sites. For these two cases, Cao et al. [6] proposed that their values were both 25 kPa, while Rollins et al. [7] proposed 16.5 and 57.7 kPa, respectively. The data proposed by Rollins et al. [7] are more reasonable and are used in this article. Other revised values in bold are as shown in Table 2, and the researchers can recheck them with the raw data from the literature [4].

Since the collection of seismic liquefaction data requires a large amount of ground motion monitoring, laboratory test analysis, and field tests, there will inevitably be a large number of missing values in the literature. For the missing values of main parameters, this article proposed two empirical formulas for repairing as follows:

$$V_s = 57.923 \times N_{120}^{0.109} \times Z^{0.147}$$

(2)

$$D_{50} = 0.259 \times \exp(0.0624 \times GC)$$

(3)

where two equations perform approximately 0.90 and 0.87 goodness-of-fit, respectively.

Corrections to $N_{120}$ and $V_s$ must take the effect of $\sigma'_v$ into consideration. The corrected $N'_{120}$ and $V_{s1}$ can be calculated as follows:

$$N'_{120} = N_{120}(ETR/90\%)\left(P_a/\sigma'_v\right)^{0.5}$$

(4)

$$V_{s1} = V_s\left(P_a/\sigma'_v\right)^{n/2}$$

(5)

where $ETR$ is the energy transfer ratio; and $P_a$ is the standard atmospheric pressure, which is set to 101.325 kPa for all the cases in this article. $n$ is the material constant that equals 0.75
and 0.65 for sandy gravel in non-liquefied and liquefied sites respectively, while it equals 0.5 for gravelly sand in both non-liquefied and liquefied sites.

In addition, the cyclic stress ratio (CSR) needs to be adjusted for the duration (expressed by magnitude) of the reference states of $M_w = 7.5$, that is the $CSR_{M_w=7.5}$ can be estimated as [10]:

$$CSR_{7.5} = CSR/MSF = 0.65r_d \frac{\sigma'_{SV}}{\sigma'_{PV}} \frac{PGA}{g} \frac{1}{MSF}$$  \hspace{1cm} (6)

$$r_d = \exp \left[ 0.106M_w + 0.118M_w \sin \left( \frac{5.142 + \frac{z}{11.28}}{11.28} \right) - 1.012 - 1.126 \sin \left( \frac{5.133 + \frac{z}{11.73}}{11.73} \right) \right]$$  \hspace{1cm} (7)

| Case No. & location | $N_{20}$ | $\sigma_v'$ (kPa) | $V_s$ (m/s) | $H_0$ (m) | $D_0$ (m) | Reference |
|------------------|----------|-------------------|-------------|-----------|-----------|-----------|
| No. 4, Nangu village | 14.1 | 154.0 | 304 | 2.7 | 2.0 | [2] |
| No. 15, Heping village | 27 | 134.0 | 305 | 0.8 | 2.9 | [2] |
| No. 16, Minan village | 17.7 | 111.0 | 259 | 0 | 3.7 | [2] |
| No. 20, Lingfeng machinery company | 18.9 | 96.0 | 233 | 3.5 | 0.6 | [3] |
| No. 27, Shuangquan village | 14.6 | 55.0 | 200 | 1.7 | 0.8 | [2] |
| No. 28, Tonglin village | 22.5 | 112.0 | 234 | 3.3 | 1.3 | [3] |
| No. 30, Linfa village | 19.5 | 100.0 | 365 | 3.2 | 1.1 | [2] |
| No. 41, Yongning village | 37.5 | 106.0 | 337 | 3.8 | 0 | [2] |
| No. 47, Quezh village | 24.6 | 155.0 | 287 | 2.0 | 4.0 | [2] |
| No. 51, Quanzhi village | 3.3 | 24.0 | 220 | 1.0 | 0.0 | [3] |
| No. 58, Finance building | 23.7 | 61.0 | 248 | 0 | 2.7 | [2] |
| No. 65, Yongsheng village | 19.5 | 98.0 | 380 | 1.6 | 1.8 | [3] |
| No. 211, Avasinis Site 2 | 27 | 98.0 | 342 | 1.6 | 1.8 | [3] |
| No. 212, Avasinis Site 3 | 12.0 | 57.7 | 198 | 1.0 | 0.0 | [3] |
\[ MSF = \begin{cases} 
(M_w/7.5)^{-2.324} \text{ for } 5.5 \leq M_w \leq 8.4 \\
(M_w/7.5)^{-2.56} \text{ for } M_w > 8.4 
\end{cases} \]  

where \( r_d \) is a shear stress reduction factor; \( g \) is the acceleration due to gravity; \( MSF \) is the magnitude scaling factor; \( z \) is the depth of interest.

**Ethics Statement**

This article did not make use of human or animal subjects, and its publication is approved by all authors.

**CRediT Author Statement**

**Jilei Hu:** Conceptualization, Methodology, Software, Supervision, Writing - Original draft preparation; **Jing Wang:** Data curation, Investigation, validation, and Visualization; **Wenjun Zou:** Writing - Reviewing, and Editing; **Bing Yang:** Investigation, validation.

**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships which have or could be perceived to have influenced the work reported in this article.

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**Supplementary Materials**

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.dib.2021.107104.

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