settlement was estimated to be around seventy-two percent (72%) of the calculated existing static settlement. The static settlement reduction value was calculated according to Priebe's method.

Table 4 below presents the estimated pre- and post-improvement long term static settlement under the proposed average and maximum mat bearing pressure.

Table 3. Hayward Baker's Dynamic Settlement Estimation

Mw	**7.35**					
GW	**+5FT or +1.5m**					
PGA	**0.635g**					
CPT	**Pre-Improvement**	**Post Improvement**	**Treatment Grid**	**ARR**	**Rrd**	**Expected Densification**
[-]	**[inch-cm]**	**[inch-cm]**	**[ftxft-mxm]**	**[%]**	**[-]**	**[Y/N]**
CPT-C01	**4.01-10.19**	3.03-7.69	12x12-3.65x3.65	4.9	0.966	N
CPT-C02	**2.87-7.29**	2.19-5.56	12x12-3.65x3.65	4.9	0.966	N
CPT-C03	**3.02-7.67**	2.08-5.28	12x12-3.65x3.65	4.9	0.966	N
CPT-C04	**3.04-7.72**	2.54-6.45	12x12-3.65x3.65	4.9	0.966	N
CPT-C05	**3.64-9.24**	2.46-6.29	12x12-3.65x3.65	4.9	0.966	N
CPT-C06	**3.14-7.98**	2.39-6.07	12x12-3.65x3.65	4.9	0.966	N
CPT-C07	**5.20-13.21**	2.89-7.34	9x9-2.74x2.74	8.7	0.942	Y
CPT-C08	**3.13-7.95**	2.45-6.22	12x12-3.65x3.65	4.9	0.966	N
CPT-C09	**3.91-9.93**	2.93-7.44	12x12-3.65x3.65	4.9	0.966	N
CPT G01	**3.70-9.40**	2.60-6.60	12x12-3.65x3.65	4.9	0.966	N
CPT-G02	**2.92-7.42**	2.25-5.72	112x12-3.65x3.65	4.9	0.966	N
CPT-G03	**4.12-10.46**	3.15-8.00	12x12-3.65x3.65	4.9	0.966	N
CPT-G04	**2.64-6.71**	2.00-5.08	12x12-3.65x3.65	4.9	0.966	N
CPT-G05	**4.20-10.67**	3.28-8.33	12x12-3.65x3.65	4.9	0.966	N
CPT-G06	**3.19-8.10**	1.95-4.95	12x12-3.65x3.65	4.9	0.966	N

Plots of HBI dynamic settlement calculation can be found in Figure 11 of this report, identifying pre- and post-improvement CPT's.

The expected total seismic and static settlement is the summation of estimated static and liquefaction-induced settlement.

CONSTRUCTION AND QUALITY CONTROL

Soil Mixing

A state-of-the-art computer-based data acquisition system measured and recorded all soil mixing parameters in real-time; and based on these parameters a real-time active control loop was used to control the grout pumping rates. The mixing parameters are graphically displayed for the soil mix rig operator. All the mixing data was uploaded to the data server, and data records were accessible remotely in real-time. The typical soil mixing data plot is provided in Figure 8.

Table 4. Hayward Baker's Long-Term Static Settlement Estimation Total Settlement

CPT	Improvement Factor*	Uniform Interior Mat Pressure=1500psf		Uniform Interior Mat Pressure=1000psf (Per Bid)	
		Pre-Improvement	Post-Improvement	Pre-Improvement	Post-Improvement
[-]	[-]	[inch-cm]	[inch-cm]	[inch-cm]	[inch-cm]
CPT-C01	1.37	0.63-1.60	0.60-1.52	0.44-1.12	0.42-1.07
CPT-C02	1.37	1.27-3.23	1.16-2.95	0.85-2.16	0.77-1.96
CPT-C03	1.37	1.31-3-33	1.22-3.10	0.96-2.43	0.89-2.26
CPT-C04	1.37	1.40-3.56	1.27-3.23	0.90-2.29	0.82-2.08
CPT-C05	1.37	0.56-1.42	0.51-1.30	0.38-0.97	0.35-0.90
CPT-C06	1.37	0.56-1.42	0.49-1.24	0.40-1.02	0.35-0.90
CPT-C07	1.37	0.26-0.66	0.23-0.58	0.18-0.46	0.16-0.41
CPT-C08	1.37	0.70-1.78	0.60-1.52	0.51-1.30	0.43-1.09
CPT-C09	1.37	0.44-1.12	0.42-1.07	0.32-0.81	0.30-0.76
CPT G01	1.37	0.71-1.80	0.66-1.68	0.52-1.32	0.48-1.22
CPT-G02	1.37	1.04-2.64	0.97-2.46	0.75-1.91	0.70-1.78
CPT-G03	1.37	0.50-1.27	0.47-1.19	0.35-0.90	0.31-0.79
CPT-G04	1.37	1.08-2.72	0.99-2.51	0.74-1.88	0.66-1.68
CPT-G05	1.37	0.43-1.09	0.39-1.00	0.31-0.79	0.28-0.71
CPT-G06	1.37	0.75-1.91	0.72-1.83	0.53-1.35	0.50-1.27

*Only applied to soil within treatment depth (to Elev-10' or -3.0m)

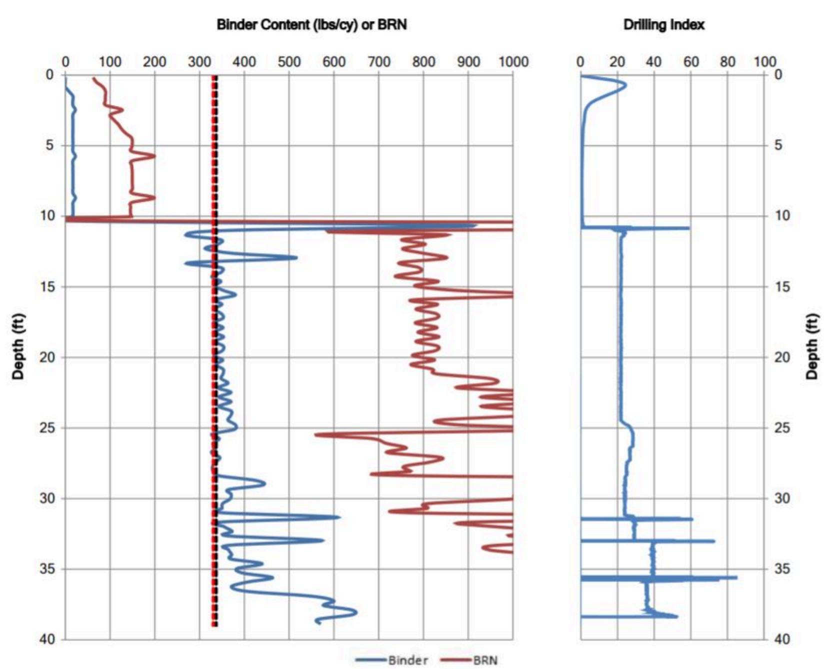

Figure 8. Wet soil mixing construction log.

For every soil mixing production day, the fresh mixing soil samples (wet samples) were retrived at random depth and cured in a moisture controlled room. The soilcrete specimens Unconfined Compressive Strength were tested at 7, 14, 28 and 56 days of age. In addition, a total of seven production DSM columns were cored full depth, with the core recoverary rate of 95% and 100%. The DSM column cores show very uniform mixing quality (see Figure 9). The selected core samples were continuesly cured in the lab for the 56 day UCS tests. The 56 day UCS values from both the wet and cored samples were statiscally analyzed, and plotted (see Figure 10).

Figure 9. Core samples from soil mix columns.

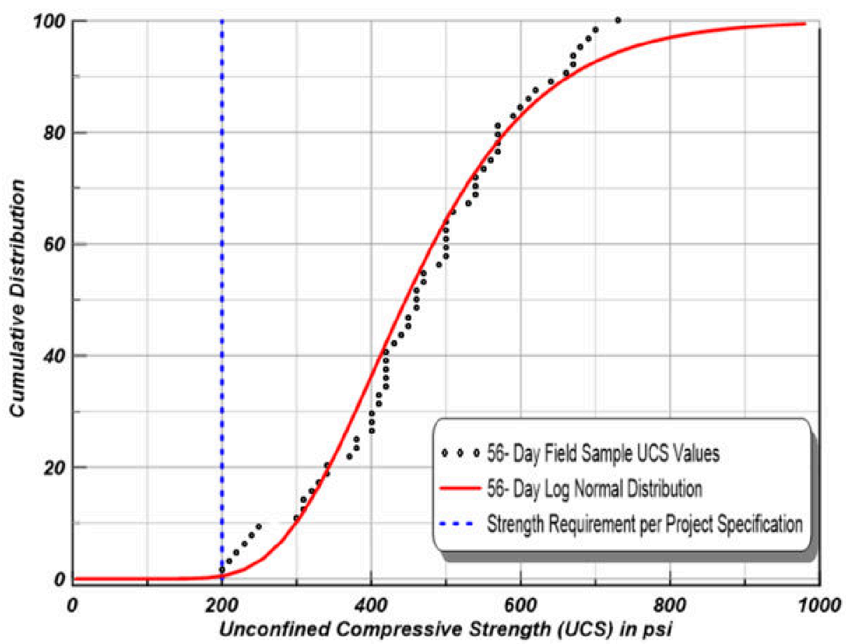

Figure 10. Statistical Analyses- 56-Day UCS Values.

Stone Column

Three-dimensional plotting tools were used for quality control during the production phase by providing the client constant feedback in terms of all measured and recorded data. Standard HBI quality control procedures were used to document all columns average amperage values and were later complied and charted (see Figure 11), identifying the soils responsiveness across all building pads. Following installation of the stone columns, verification testing was performed using a series of modulus tests and CPT soundings.

a) For areas whose stone column replacement ratios greater or equal than 8.7% ARR, Production work was evaluated using a total of three CPTs randomly selected in the ground improvement areas. All three CPTs showed measurable densification within sand soil layers, and the post-improvement calculated static and seismic settlement are well within expectation (see Figure 12).

b) For areas whose stone column replacement ratios less than 8.7% ARR, Production work was evaluated using a total of four modulus tests randomly selected in the ground improvement areas. One modulus test per building pad. These tests were used to confirm the assumed shear modulus and subgrade modulus used in the design. In addition, HBI performed four additional post-improvement CPTs to confirm settlements. The actual modulus values obtained from the tests are: 429 pci (116MPa/m), 342 pci (93MPa/m), 428 pci (116MPa/m), and 531 pci (144MPa/m). Calculated post-improvement settlement of all four CPTs are well within expectation.

The combined as-built stone columns and deep soil mixing columns plan is based on actual GPS-surveyed locations.

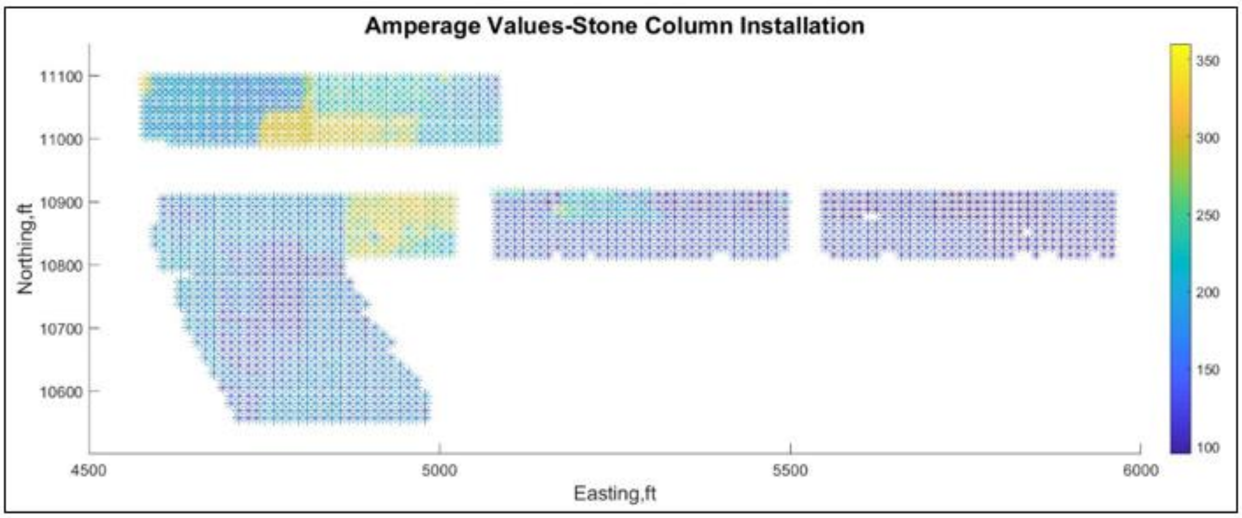

Figure 11. Amperage values during Stone Columns Installation.

CONCLUSIONS

This paper describes a case history where soilcrete panels in combination with stone columns were implemented to provide adequate matt foundation support during a high seismic risk event. The soilcrete panels provided a buttress to mitigate lateral spreading potential to an acceptable level as well provided temporary shoring for the subterranean foundation excavation. Stone columns provided additional foundation bearing support and reduce potential settlement (both static and seismic) to within tolerable levels for a structural matt foundation. The soil mixing production was enhanced by utilizing real-time data acquisition and active feedback control systems ensuring that the correct mixing energy and binder content was introduced to the soil. Stone column work was verified by series of post-improvement CPTs and modulus tests.

The deep soil mixing and stone column work was completed in May 2017. Since then, the County of Los Angeles has approved the stabilization work for the Neptune project. A current aerial view (see Figure 13) shows the Building 4, temporary excavation operation in process, and

Buildings 1, 2, and 3 matt foundations and upper building structure in construction.

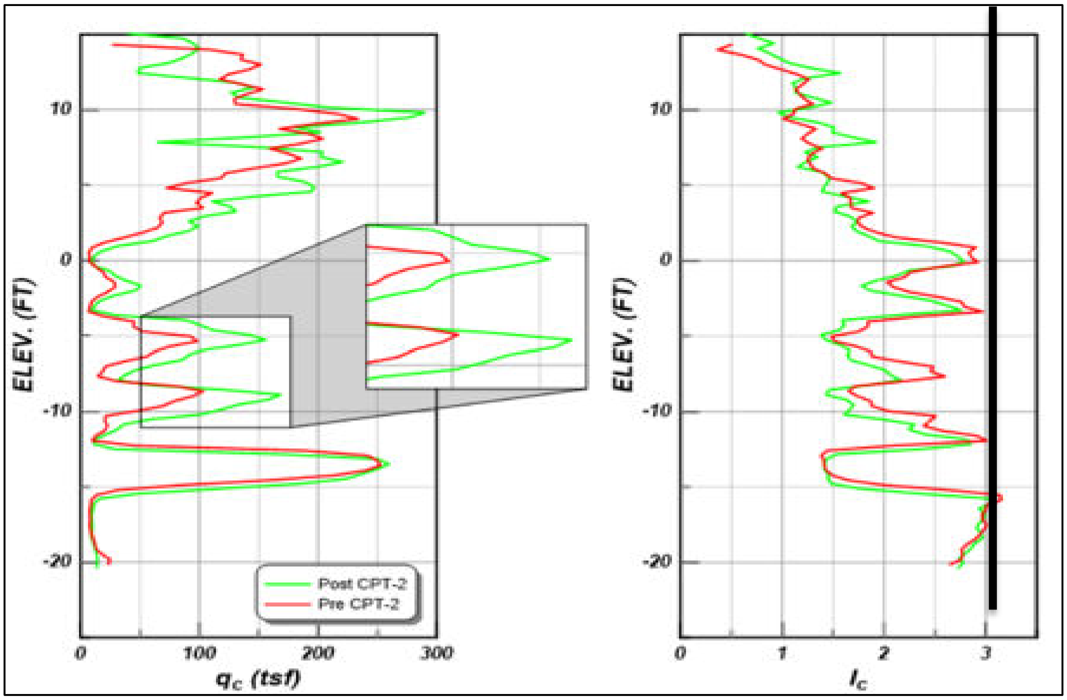

Figure 12- Pre and Post CPT Comparison.

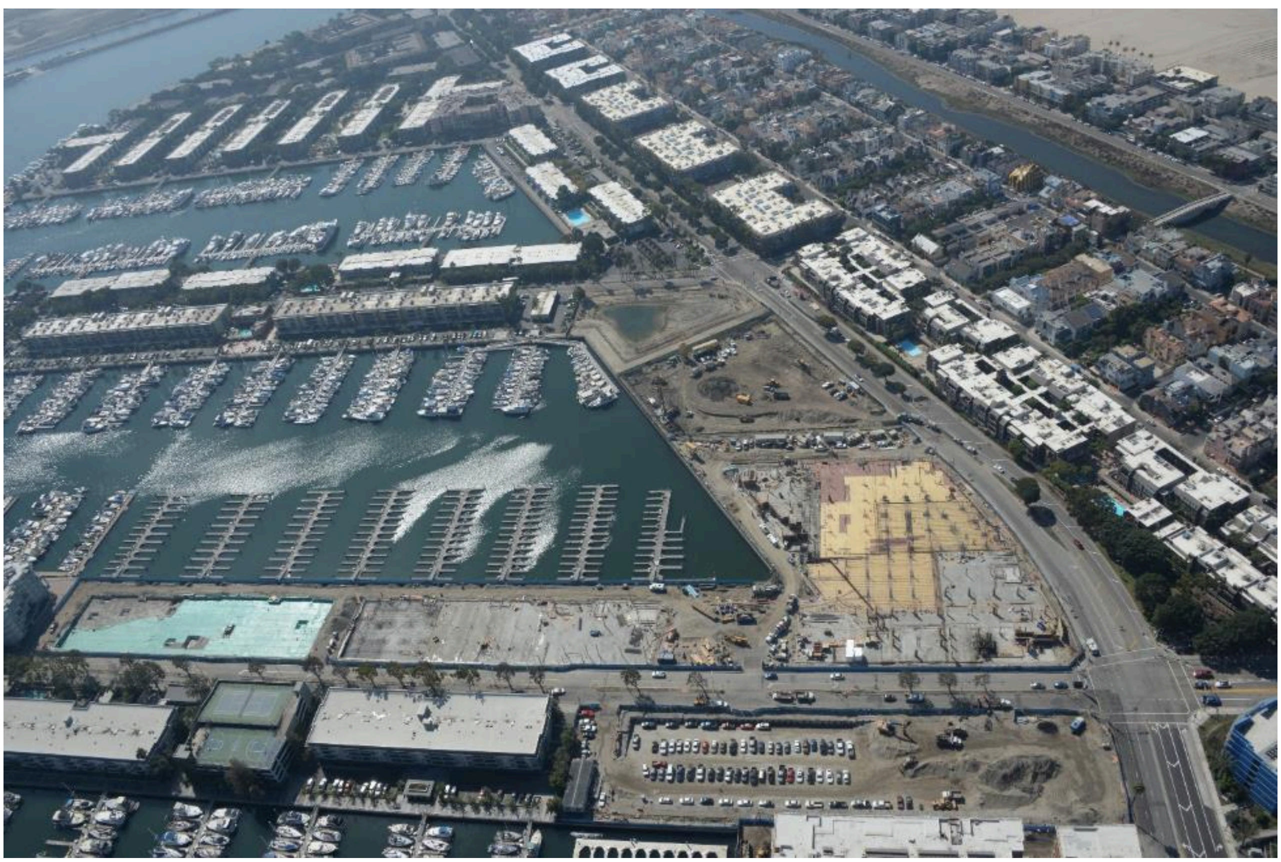

Figure 13: Aerial photo of Neptune project construction at Marine Del Ray, California

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Next-Generation Liquefaction (NGL) Case History Database Structure

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ABSTRACT

This paper presents the organizational structure (schema) of the next-generation liquefaction (NGL) relational database. The schema describes the tables, fields, and relationships among the tables, and provides an important resource for users who wish to interact with the database by writing queries. Structured relational databases are not commonly utilized in the natural hazards community, where file repositories are more commonly used and often called "databases". This paper also discusses what a relational database is, and why this approach was adopted for the NGL project.

INTRODUCTION

The Next-Generation Liquefaction (NGL) project is a multi-year community-based effort consisting of three components: (1) a transparent, open-source, community database of liquefaction case histories, (2) supporting studies for effects that should be captured in models but that cannot be constrained by case history data, and (3) model development (Stewart et al. 2016). This paper addresses the structure of the case history database that is accessible via a web interface at http://www.uclageo.com/NGL/ (last accessed 02/06/2018). Registered users can upload, view, and download data. The database was developed using the My Structured Query Language (MySQL) relational database management system (RDBMS). The web interface was developed using PHP: Hypertext Preprocessor (PHP), Hypertext Markup Language 5 (HTML5), and Javascript and also utilizes the Environmental Systems Research Institute (ESRI) Arc Geographic Information System (ArcGIS) Application Program Interface (API) and the Leaflet Javascript API to organize the data geo-spatially.

The essential data requirements for the NGL database were developed over a few years through a series of national and international community workshops. A draft version of the database was presented in a workshop at the University of California, Berkeley, in July 2017, and this paper presents an updated version of the database reflecting community input. While the database structure, as described here, is essentially complete, the database itself has only begun to be populated. The task of populating the database is an ongoing community task being overseen by the NGL Database Working Group consisting of the first author (chair), K. Onder Cetin, Kevin W. Franke, and Robb E.S. Moss.

The NGL database is a relational database, which differs from what many in the natural hazards community intend when they use the term "database". Often, data are organized into file repositories, which strictly-speaking should not be called databases. This paper first briefly describes relational databases, and explains why this approach was adopted for NGL. The paper then presents the organizational structure of the database, describing the tables, fields, and relationships among tables, which is called a schema. We anticipate that this paper will serve as an important resource for future users of the database who wish to write queries to extract data using the Structured Query Language (SQL).

WHAT IS A "DATABASE"?

The word "database" is often used by the natural hazard engineering community in a rather loose manner to mean a collection of data. However, this is not the definition widely agreed upon by the computer science community. Rather, a relational database (RDB) is a structured body of related information organized into inter-related tables formally described by a schema. Tables are related to each other by shared fields called "keys", where a *primary key* is a unique identifier for each record, and a *foreign key* is a field in one table that identifies a record in another table.

To illustrate the benefit of an RDB, consider the hypothetical information contained in Table 1 describing two different earthquake events that were each recorded by two ground motion stations. Each row corresponds to a specific ground motion record, and information about the earthquake must be repeated each time a new record is inserted into the table. Repeating information in a table presents the possibility for data inconsistencies because a user might accidentally type the event name, magnitude, or other fields incorrectly. Furthermore, the earthquake magnitude would need to be updated at potentially many different positions within the table if it happened to be revised at some point in the future. An RDB eliminates such problems by organizing all relevant information in different tables and defining relationships among them. This results in a structure that avoids repetitions and null fields.

Table 1. Hypothetical earthquake event, station, and ground motion information.

Event Name	Magnitude	Epicentral Latitude	Epicentral Longitude	Station Name	V_{s30} (m/s)	R_{jb} (km)	PGA (g)
Westwood Hills	6.3	34.0689	118.4452	Factor Building	380	2	0.84
Westwood Hills	6.3	34.0689	118.4452	Santa Monica Courthouse	215	14	0.28
Hollywood Valley	7.2	34.1027	118.3404	Factor Building	380	20	0.61
Hollywood Valley	7.2	34.1027	118.3404	Santa Monica Courthouse	215	30	0.32

The data in Table 1 contains three different types of information:

- Event: event name, magnitude, latitude and longitude of epicenter;
- Station: recording station name and time-averaged shear wave velocity in the upper 30 m (V_{s30});
- Information specific to a recorded ground motion: distance to surface projection of fault, R_{jb}, and ground motion intensity, PGA.

The information should therefore logically be organized into three tables, as illustrated in Tables 2–4. Each entry is assigned a unique primary key, which in this case is an integer under entry names Event_id, Station_id, and Motion_id. The event name could potentially be the primary key for the Event table because the event name is unique. However, integers facilitate faster searches than long character strings, and it's possible that the event name could be modified at some point in the future if, for example, the epicenter location is modified. For these reasons, introducing an integer primary key is common practice. In addition to a primary key, the Motion table contains foreign keys that relate a particular motion to a particular event and to a particular recording station.

Dividing the information among three tables may seem unnecessarily complicated, but the structure presented in Tables 2–4 offers significant benefits over that in Table 1. Information for each event and station is entered only once, which eliminates the possibility for inconsistencies due to data entry errors, and also eliminates the need for updating multiple cells when an entry needs to be modified. The benefit of this structure may not seem significant for the small dataset used in this example, but it is easy to imagine the benefits realized for large datasets containing thousands of ground motion records from hundreds of events. The data presented in Tables 2–4 is said to be in the "third normal form" (Codd, 1972) because all of the entries are non-transitively dependent on the primary key. This means that each column entry can be derived by knowledge of the primary key, and that no column logically depends on any other column besides the primary key.

Table 2. Earthquake event table.

Event_id	Event Name	Magnitude	Epicentral Latitude	Epicentral Longitude
1	Westwood Hills	6.3	34.0689	118.4452
2	Hollywood Valley	7.2	34.1027	118.3404

Primary Key
Foreign Key

Table 3. Recording station table.

Station_id	Station Name	V_{S30} (m/s)
1	Factor Building	380
2	Santa Monica Courthouse	215

NGL DATABASE STRUCTURE

One goal of the NGL project is to develop a transparent, open source, community database of case histories of liquefaction, ground failure, and non-ground failure (Stewart et al. 2016). This section describes the NGL case history database and its organization. In NGL, a case-history consists of three components: (1) geotechnical/geological site characterization, (2) observed field performance, including evidence for liquefaction and its effects, ground failure, or non-ground failure, and (3) earthquake event and ground motion information. The NGL database consists of 43 tables (10 for general information, 24 for site characterization, 5 for field performance observations, and 4 for earthquake events). Its structure is described by the database schema which represents the blueprint of how the database is constructed. The schema also defines relationships among tables through a formal definition of primary and foreign keys. The current version of the NGL schema has been refined through a community-based effort performed in the last two years via project coordination meetings and public workshops.

Table 4. Ground motion table.

Motion_id	Event_id	Station_id	R_{jb} (km)	PGA (g
1	1	1	2	0.84
2	1	2	14	0.28
3	2	1	20	0.61
4	2	2	30	0.32

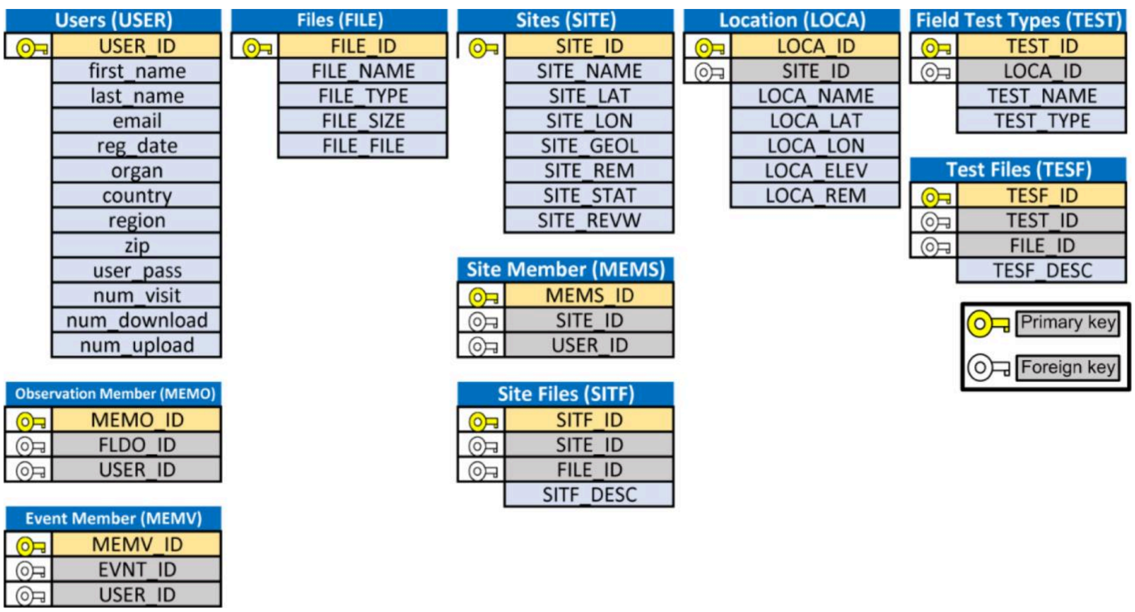

Figure 1. Relational database structure for general information.

Figure 1 defines the content of various type of tables in the database. The *Users* table contains information about NGL database account holders, with USER_ID as the primary key. Along with individual users, information for each component of the database (site, observation, and event), can be accessed and modified by members of a research team (groups of one or more users) with permissions to access information uploaded by members of the team. Tables *Site Member* (MEMS), *Observation Member* (MEMO), and *Event Member* (MEMV), can be considered as junction tables, as they set the relationship between users and the research team(s) they belong to. A *site* represents a broad area for which related information such as site investigation and post-earthquake observations are available. Although sites are assigned a latitude and longitude for the purpose of plotting them on a map, they may occupy an area rather than a point, which is often required in the documentation of case histories due to spatial variations of field performance (e.g., across the domain of a lateral spread) and geotechnical conditions. The site's geodetic coordinates are used only to plot the site on a map.

A *location* is a specific geo-referenced point within a site where site investigations are performed or an observation is made. Many locations may be assigned to a single site. A single location may contain more than one field investigation. Each individual field investigation type is assigned as a single entry in the *Test* table. As an example, at a given location, a borehole and a downhole test may be performed. They will share the same location (i.e. the same coordinates),