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Development of an integrated Web-based system with a pile load test database and pre-analyzed data

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Abstract. A Web-based pile load test (WBPLT) system was developed and implemented in this study. Object-oriented and concept-based software design techniques were adopted to integrate the pile load test database into the system. A total of 673 case histories of pile load test were included in the database. The data consisted of drilled shaft and driven precast concrete pile axial load tests in drained, undrained, and gravel loading conditions as well as pre-analyzed data and back-calculated design parameters. Unified modeling language, a standard software design tool, was utilized to design the WBPLT system architecture with five major concept-based components. These components provide the static structure and dynamic behavior of system message flows in a visualized manner. The open-source Apache Web server is the building block of the WBPLT system, and PHP Web programming language implements the operation of the WBPLT components, particularly the automatic translation of user query into structured query language. A simple search and inexpensive query can be implemented through the Internet browser. The pile load test database is helpful, and data can be easily retrieved and utilized worldwide for research and advanced applications.

Keywords: pile; load tests; database; web-based; internet

1. Introduction

Deep foundations are underground structures founded deep below the ground surface. The actual subsurface condition cannot be visually inspected or controlled during construction. This condition makes pile capacity, among other factors, equally dependent on the geological condition and the quality of the construction. Such uncertainty entails the need to verify the reliability of the

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foundation through a pile load test. A pile load test (PLT) is an integral part of construction often required in projects because it is crucial in assessing the final design of foundation structures.

Many field load tests have been conducted over the years. The results of these tests are stored as flat-file data by geotechnical testing companies, engineers, designers, and researchers. This method of preservation restricts the capability of these data to be fully useful. In addition, searching for the specific information is difficult, restrictive, and time consuming because of the possible lack of a well-organized data management procedure. One solution to address this issue is to develop a PLT database.

Early studies (Long and Shimel 1989, Wysockey and Long 1994) focused on constructing a database of field load tests on drilled shafts. Long and Shimel (1989) developed a relational database of high-quality load tests to study the parameters that affect the axial behavior of drilled shafts as well as analysis methods to predict axial capacity. Wysockey and Long (1994) created a database of axial load tests on drilled shafts and concluded that the usefulness of a database is highly dependent on the quality and details of reported data. Lan (2004) likewise established a database of large-diameter bored piles through Microsoft Access and explored the effect of different pile sizes on foundation behavior.

Recent studies on database development were conducted by Zhang and Wang (2009), Lin *et al.* (2012), Marcos *et al.* (2012). Zhang and Wang (2009) developed a driven pile database for the study of construction effects. Lin et al. (2012) and Marcos *et al.* (2012) developed a database containing many drilled shaft case histories of static load tests for the geotechnical community. They developed the drilled shaft load test (DSLT) database, which contains information that can be accessed by simple browsing or downloaded for advanced applications. In addition, more researchers (e.g., Hyslop *et al.* 2010, Eeckhaut and Hervás 2012, Bica *et al.* 2013, Chen *et al.* 2013) developed database to explore the related civil and geotechnical issues.

The PLT database, which is an expanded version of the DSLT database, was utilized in this study. The PLT database contains useful field data that serve as a pool of information. These data include information on basic drilled shafts and driven precast concrete piles, soil investigation, static load test results, and pre-analyzed pile data. Structured query language (SQL) is the only means to access the PLT database. Although the use of SQL is manageable, the ease of data retrieval for any desired information requires familiarity with the language. Without any background on SQL, data retrieval from PLT is difficult.

Therefore, the development of a web-based pile load test (WBPLT) system is essential because such system would provide an easy and efficient method of accessing PLT even without prior knowledge of SQL. The PLT database can be accessed via an Internet Web browser with a user-friendly interface and without the use of SQL syntax. WBPLT allows convenient access to data from simple browsing to collecting large quantities of essential pile information. The mechanism of the WBPLT system aims to maximize the effectiveness of storing, retrieving, and managing huge amounts of data. Furthermore, the quality of pile design, analysis, and research can be significantly enhanced through this system. Information is available anywhere in the world through the Internet, and the platform allows interested engineers to extend this system by uploading useful load test data.

The WBPLT system was developed and implemented in this study. The system was designed with object-oriented and concept-based techniques for extensibility and flexibility. The employment of the system architecture and implementation of WBPLT were clearly described. Lastly, a system demonstration was performed to demonstrate the applicability of the WBPLT system.

2. System architecture

WBPLT comprises several concepts. A concept is a requirement or a certain behavior; it involves the abstraction of a thing. From the point of view of software engineers, concepts can be represented by components, a user-defined type, or a module of a software system in an object-oriented community. The basic concepts of WBPLT include the user interface, translation of an SQL command to generate results in a tabular format, and the PLT database. Fig. 1 shows the system architecture of WBPLT, which consists of five major components, namely, presentation manager, controller, commander, reporter, and the PLT database.

The presentation manager provides the Web browser interface. It is responsible for receiving the request of the client, sending the request to the commander through the controller, and returning the query results to the client. It assists in the two-way interaction between the client and the WBPLT system.

The controller acts as a message communicator for the WBPLT system. When the presentation manager receives a client request, the request is sent to the controller, which then requests the commander for an SQL command translation. When the reporter finishes tabulating the query results, the data in tabular form are sent to the controller. The controller then sends the information back to the presentation manager. The result is received by the client through the Web browser.

The commander automatically translates the query commands into standard SQL syntax. The request is retrieved from the PLT database according to the SQL syntax provided by the commander. The reporter generates tables of query results from the database and sends the information to the presentation manager through the controller. The query result is displayed in a tabular format.

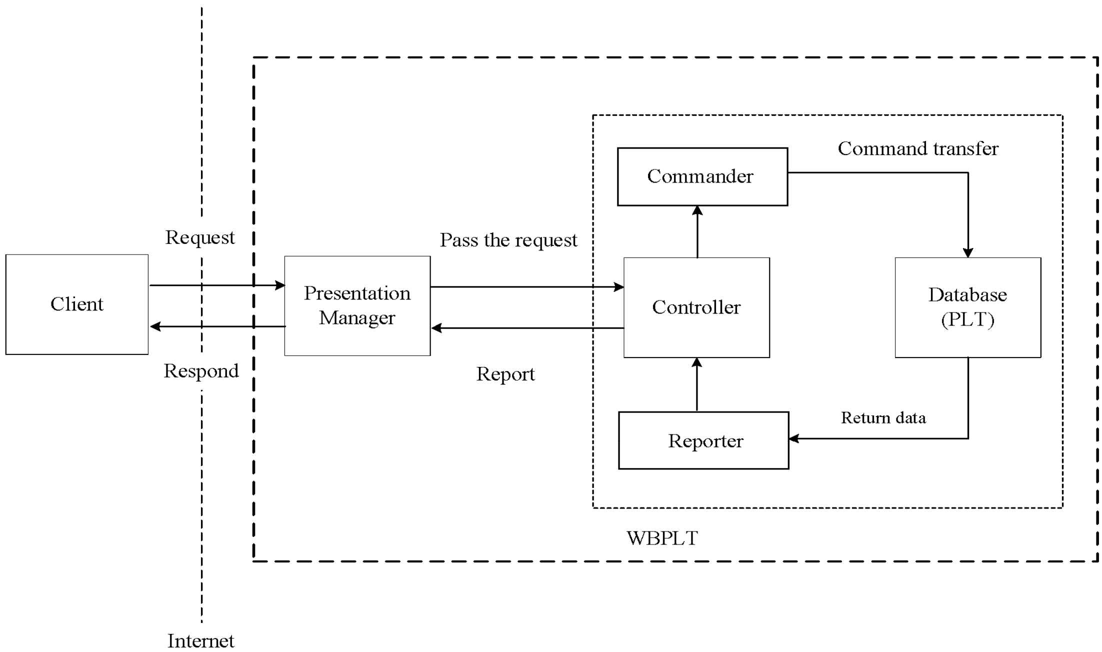


Fig. 1 WBPLT system architecture

The PLT database is a data storage system that contains PLT information and pre-analyzed data. It is a relational database designed with the entity-relationship diagram (ERD) developed by Chen (1976). The entity-relationship model design for relational databases has more advantages in terms of flat-file storage. Fig. 2 shows the ERD for the PLT database structure. The entities, attributes, and relationships are presented in Table 1. Ten entities were developed for the design of the PLT database: site (location information), soil (soil information), pile (pile information), and reference (literature) as well as pre-analyzed information, including desparameter (design parameters), capacity (load carrying capacity), capacity_detail (capacity relative to the pile tip or side), displacement (settlement), pile_has_ref, and soil_has_pile, which are associated entities. The details on the database architecture and ERD are similar to those presented by Lin *et al*. (2012) and Marcos *et al*. (2012).

3. System implementation

Unified modeling language (UML; Booch *et al*. 2001), a standard visual language for software development, was adopted to establish the WBPLT system model. UML can produce a standard system diagram that can provide a good representation of system functions and processes. The static structure of the five components was described by the UML class diagram. The system class diagram is presented in Fig. 3 to define the name, operation (or method), and responsibility of each class. The figure also illustrates the aggregate relationship between classes. Four classes were developed; these classes and their functions in the system are shown in Fig. 3. The controller is the core component of the entire system; it controls message transfer among the presentation manager, commander, and reporter. The presentation manager receives the request through the "ReceiveRequest ()" operation and responds to the client request through the "RespondResult ()"

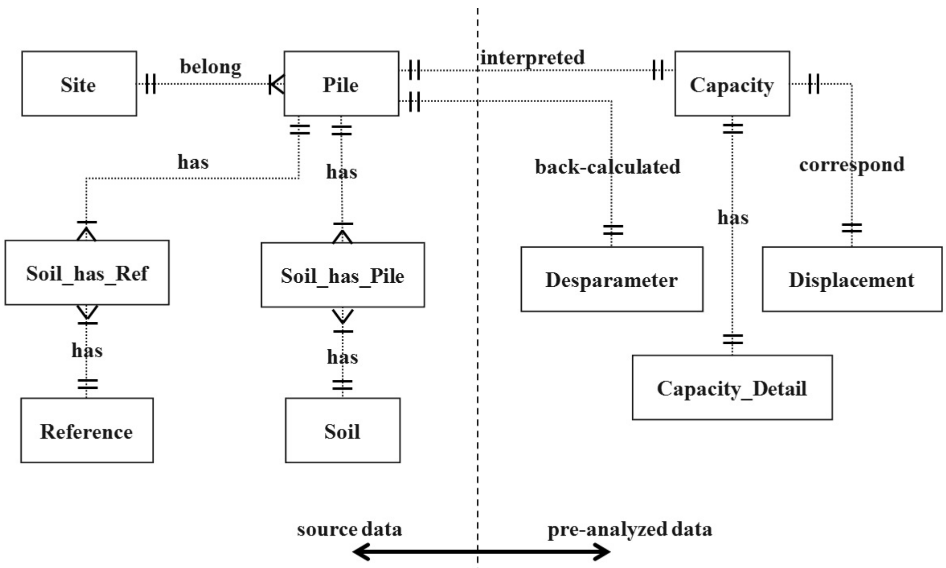


Fig. 2 Entity-relationship diagram (ERD)

Table 1 PLT entities and attributes

Entity	Attribute	Entity	Attribute
Soil	Soil location	Site	Site No.
	SPT N		Country
	CPT		Test location
	D_r		Latitude longitude
	LL		Soil description
	PL		GWT (m)
	Water content (%)	Capacity and displacement	10 Interpretation criteria
	Unit weight		
	s_u test type	Capacity detail	L_1 side resistance
	s_u		L_1 tip resistance
	Friction angle		L_2 side resistance
Pile	Pile No.		L_2 tip resistance
	Test date		Chin side resistance
	Pile type		Chin tip resistance
	Shape	Desparameter	s_u CIUC
	Loading type		Alpha CIUC
	Depth, D (m)		Measured beta
	Dia./Width, B (m)		predicted beta
	D/B		Lambda CIUC
	Const. method		K_o
	Equipment		K/K_o
	Hammer type		N_q
	Rated energy		N_γ
	Final set		N_q modifier for shape
	Strain gauge		N_q modifier for soil rigidity
	Load displacement curve		N_c modifier for shape
	Layer information		N_c modifier for depth
	Load transfer		N_γ modifier for soil rigidity
	Tip resistance	Reference	Reference
	Side resistance		
	Remarks		

operation. The "SendRequest ()" operation of the controller then transfers the request to the commander. The "GetResult ()" operation of the controller receives the tabular results from the reporter. The "TransformRequestToSQLSyntax ()" operation of the commander translates user requests from the controller to the corresponding SQL command. Finally, the reporter's "GenerateTable ()" operation generates the corresponding query results in a tabular form.

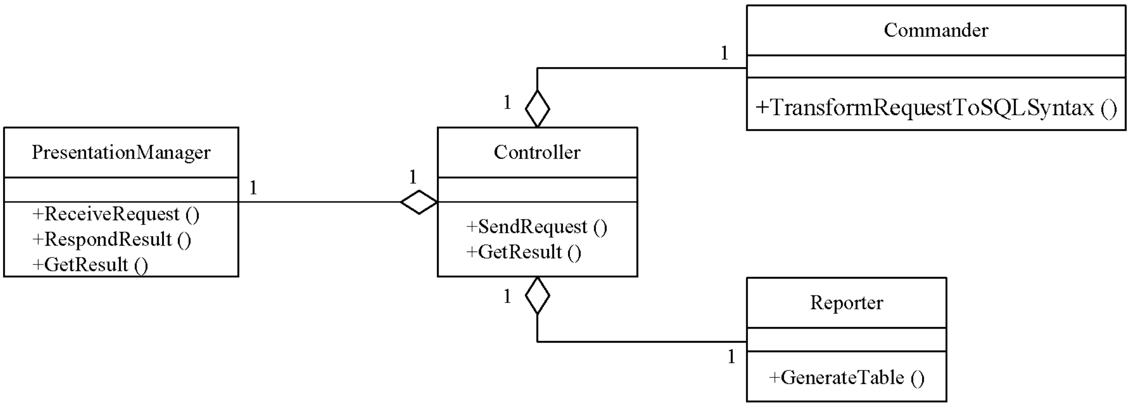


Fig. 3 WBPLT system class diagram

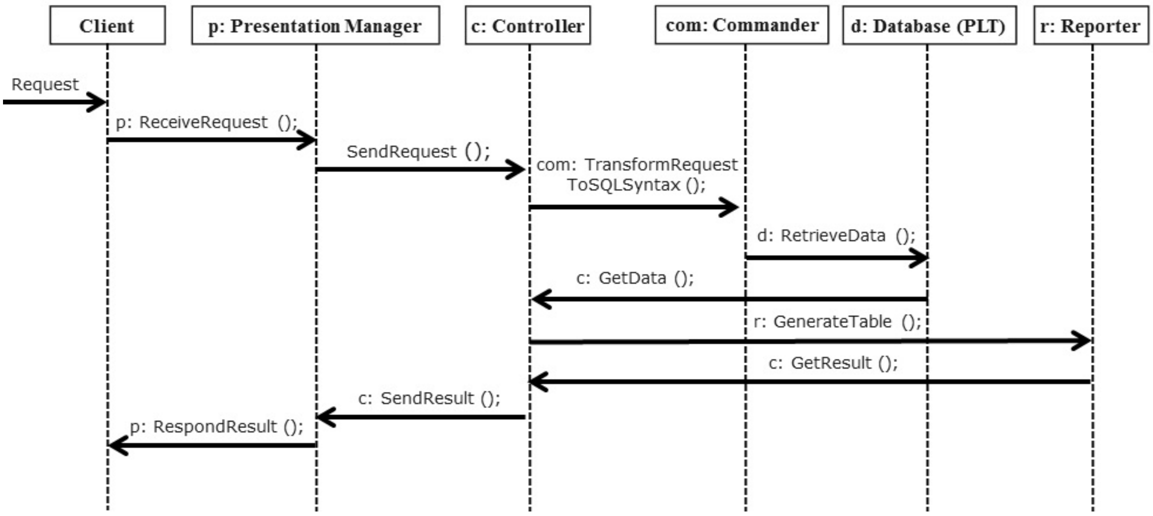


Fig. 4 WBPLT system sequence diagram

Fig. 4 shows a sequence diagram of the WBPLT system with emphasizes on the sequence of sending and receiving messages from one class to another. The figure helps explain the interaction and the dynamic behavior of the system. The actual operating scenario of the system is described below:

Six objects are included in the sequence diagram: client, p (notation for presentation manager class), c (notation for controller class), com (notation for commander class), d (PLT database), and r (notation for reporter class). When the client makes a query, the query triggers p's ReceiveRequest () operation to obtain requests from the client. c's SendRequest() operation then sends the request to the com. The next call is com.TransformRequestToSQLSyntax (); it is an operation of the commander that transforms the request into SQL syntax. The generated SQL query syntax is applied to retrieve the results from the PLT database by making a call for RetrieveData ()

operation. The query result is sent back to c, the controller, with a call for the controller's GetData () operation. After finishing the operation r.GenerateTable() called by the com object, the query results are generated in a well-tabulated format by object r. The client can browse the tabular results from object p through a series of operation calls: c.GetResult(), p.GetResult(), and p.RespondResult().

From the TransformRequestToSQLSyntax() operation in Fig. 4, the conversion mechanism of the client request into SQL syntax is demonstrated as follows:

(1) Simple query: Fig. 5(a) provides an example of a simple query in which the commander transforms the user request into SQL represented by the "$qstring" variable. Fig. 5(b) presents the Q-Items, which are desired query options from the user interface. The value of table.`column` is replaced accordingly based on the Q-Items to retrieve data. $qstring can be divided into three parts. The first part, the "Select" command, is where the desired data are selected. The asterisk symbol (*) represents "all data." The second part, the "From" command, generates data from the database for retrieval. This section is difficult to manage when the user is not familiar with the PLT database structure because of the possible complexity of SQL. However, this part of the query is automatically generated based on user selection from the Q-Items. The third part, the "Where" command, relates to the search conditions displayed on the user interface. For instance, if compression (Q-Item) is selected as the loading type, the system would automatically convert pile.`LoadingType` (table.`column`) into compression. This process applies to the other Q-Items. This part of the system eliminates the process of SQL encoding for querying.

(2) Complex query: Fig. 6(a) illustrates the transformation of SQL for a query involving several search conditions. For instance, specific data based on loading type and soil type and with information on capacity range from a specific interpretation criterion are desired. The user can initially select the desired data for loading type (Q-Item), such as compression or uplift, filter the soil type (i.e., drained, undrained, or gravel), and select the

(a)

```
function TransformRequestToSQLSyntax () {
.
.
.
$qstring= "Select*

        From shaft
        Inner Join site ON site.idSite = shaft.site_idSite
        Inner Join soil ON site.idSite = soil.site_idSite
        Inner Join soil_has_shaft ON soil.idSoil = soil_has_shaft.soil_idSoil AND
         shaft.idShaft = soil_has_shaft.shaft_idShaft
         Inner Join desparameter ON shaft.idShaft = desparameter.shaft_idShaft
         Inner Join capacity ON capacity.shaft_idShaft = shaft.idShaft
         Inner Join displacement ON capacity.Displacement_idDisplacement =
        displacement.idDisplacement

        where table.`column` = ' Q-Item ' ";
.
.
.
}
```

(b)

Q-Item	table.`column`
Compression Uplift	shaft.`LoadingType`
Drained Undrained Gravel	soil.`soiltype`
Australia Brazil Canada China Korea Taiwan ↓	site.`Country`

Fig. 5 Simple query SQL conversion mechanism

interpretation criterion and the range of interpreted capacity. Fig. 6(a) shows the transformational SQL inside the commander for this query. Similarly, the first and second parts of $qstring contain the data acquisition language. The third part, desired information based on user selection, is automatically converted into Q-Item (1) and Q-Item (2) for loading type and soil type, respectively. The Q-Method relates to the interpretation criterion, and Q-Value relates to the range of the interpreted capacity. Fig. 6(b) shows that every option is converted by the system. The commander combines the processes to quickly generate SQL query syntax for data retrieval.

The translation of a command into SQL by the commander provides ease in querying. Users do not need to personally encode the SQL syntax as an additional procedure. The commander provides a comfortable and friendly interface, a simple method of querying, and quick retrieval of data. Message transfer (presentation manager) is implemented with the Apache server, and PHP Hypertext Preprocessor is utilized to implement the controller, commander, and reporter operations.

Fig. 4 shows that the PLT database has an important role in the sequence diagram and data retrieval. PLT is managed by the MySQL database management system, a relational database in which information in multiple tables is designed according to ERD. In this study, 90 additional case histories of drilled shaft in gravels and 232 cases of driven pile precast concrete piles in drained and undrained soils were incorporated into the original database of DSLT (Lin *et al*. 2012) and renamed as PLT for data utility. Data from 673 pile load test data, including information on the original pile load test, in-situ information, soil test results, construction methods, and

(a)

```
function TransformRequestToSQLSyntax () {
.
.
.
$qstring= "Select*
        From shaft
        Inner Join site ON site.idSite = shaft.site_idSite
        Inner Join soil ON site.idSite = soil.site_idSite
        Inner Join soil_has_shaft ON soil.idSoil = soil_has_shaft.soil_idSoil AND
       shaft.idShaft = soil_has_shaft.shaft_idShaft
        Inner Join desparameter ON shaft.idShaft = desparameter.shaft_idShaft
        Inner Join capacity ON capacity.shaft_idShaft = shaft.idShaft
        Inner Join displacement ON capacity.Displacement_idDisplacement =
        displacement.idDisplacement

      where shaft.`LoadingType`=' Q-Item (1) ' AND soil.`soiltype`=' Q-Item (2) '
      AND capacity.`capacitychoose`=' Q-Method '

       HAVING capacitychoose < ' Q-Value '
.
.
.
}
```

(b)

Query	Option
Q-Item(1) (Loading Type)	1. Compression 2. Uplift
Q-Item(2) (Soil Type)	1. Drained 2. Undrained 3. Gravel
Q-Method	1. L_1 2. 0.5in 3. L_2 4. 4%B 5. ST 6. Fuller and Hoy ↓
Q-Value	Any value

Fig. 6 Complex query SQL conversion mechanism

pre-analyzed capacity and design parameters, can be retrieved from the database. Relevant pile and soil information, such as the longitude and latitude of the test site, test date, number of reinforcement, load transfer, soil layer information, pile shape, hammer type, rated energy, and final set, have also been added to the database. Table 2 shows the 10 interpretation criteria utilized to determine the interpreted capacities in the database (Chen *et al*. 2008, Chen and Fang 2009, Chen and Chu 2012, Marcos *et al*. 2013). Table 3 presents the analytical models for tip and side resistances utilized for the back-calculated design parameters. The tip resistance adopts general bearing capacity equation, while side resistance includes α, β, and λ analysis methods. The details of these analysis models are presented elsewhere (Chen *et al*. 2009, 2011).

Table 2 Interpretation criteria in the PLT database

Interpretation criterion	Description
L_1-L_2	Hirany and Kulhawy's method (2002)
0.5 in	load at 0.5 in displacement
4%B	load at 4%B displacement (B = pile diameter)
Slope tangent	O'Rourke and Kulhawy's method (1985)
Fuller and Hoy (1970)	Fuller and Hoy's method (1970)
Terzaghi and Peck (1967)	Terzaghi and Peck's method (1967)
DeBeer (1970)	DeBeer's method (1970)
Van der Veen (1953)	Van der Veen's method (1953)
Chin (1970)	Chin's method (1970)
Davisson (1972)	Davisson's method (1972)

Table 3 Analytical models for back-analyses

	Drained	Undrained
Tip resistance	$q_{ult} = \bar{q} N_q \zeta_{qs} \zeta_{qd} \zeta_{qr} + 0.5 \bar{\gamma} B N_\gamma \zeta_{\gamma s} \zeta_{\gamma d} \zeta_{\gamma r}$	$q_{ult} = 5.14 s_u \zeta_{cs} \zeta_{cd} \zeta_{cr} + q \zeta_{qs} \zeta_{qd} \zeta_{qr}$
Side resistance		$Q_s(\alpha) = p \sum_{n=1}^{N} \alpha_n s_{un} t_n$ $Q_s(\lambda) = p\lambda(\bar{\sigma}_{vm} + 2 s_{um})t$
	$Q_s(\beta) = p \sum_{n=1}^{N} \bar{\sigma}_{vn} K_{on} \tan\left[\bar{\phi}_n \cdot \frac{\delta}{\bar{\phi}}\right] t_n$	

*Note: q_{ult} = ultimate tip capacity, Q_s = side resistance, α = empirical adhesion factor, $\beta = K \tan\delta$, λ = empirical factor, s_u = soil undrained shear strength, ζ_{cs}, ζ_{cd}, ζ_{cr} = modifiers of N_c for foundation shape, depth and soil rigidity, respectively, ζ_{qs}, ζ_{qd}, ζ_{qr} = modifiers of N_q for foundation shape, depth, and soil rigidity, respectively, $\zeta_{\gamma s}$, $\zeta_{\gamma d}$, $\zeta_{\gamma r}$ = modifier of N_γ for foundation shape, depth and soil rigidity, respectively, (N_c, N_q, N_γ = bearing capacity factors), q = total vertical stress, $\bar{q}$ = effective vertical stress, $\bar{\gamma}$ = soil effective unit weight, p = pile perimeter, N = number of soil layers, t = thickness, K = coefficient of horizontal soil stress, K_o = in-situ K, $\bar{\sigma}_v$ = vertical effective stress, $\bar{\sigma}_{vm}$ = mean vertical effective stress, $\bar{\phi}$ = soil effective stress friction angle, δ = interface friction angle for soil and shaft

Figs. 7(a)-(c) show a schematic of the WBPLT web platform, home page, and main page. Fig. 7(a) shows the details of the four general links in the main page (Fig. 7(c)): database introduction, data information, query, and upload. The database introduction link presents the contents and structure of the database. The data information link provides a detailed tabulated description of the table headings of the stored data in the system. The query link is further subdivided to provide a variety of search options. The query can be based on load type, soil type, capacity range, and country. Fig. 7(a) presents the data options for each query type. The content reveals that the database provides a wide range of information that can be easily accessed by engineers and researchers and can be utilized in research, construction, and design. Lastly, the data upload link is incorporated. This link allows the geotechnical community to upload essential pile load test information to the system. The link also allows the addition of these data to the database at any time so as to enhance the content of the database.

4. System demonstration

The WBPLT system consists of the presentation manager as the front-end user interface and the controller, commander, reporter, and PLT database as the back-end interface. The client screen interacts with the presentation manager; the latter is linked to the back-end of the system to automatically convert queries into SQL language and organize these queries into a tabular format before they are presented to the user by the presentation manager. The user can quickly acquire important and useful data from the database through this interaction.

The WBPLT system can be conveniently accessed via the URL (http://140.135.120.167/CYCU welcome). The user interface was designed by incorporating Chinese (Mandarin) and English, thereby allowing users around the world to access the system. Fig. 7(b) shows the home page and Fig. 7(c) shows the main page where the links for major selection are displayed. These links include introduction, data information, query, and upload. The pages for introduction and data information are illustrated in Figs. 8(a)-(b), respectively. The introduction presents the database content and the number of pile load tests for drilled shafts. Data include detailed descriptions and abbreviations of the information contained in the database. The most important link is query, which is subdivided into four categories as described previously.

Simple queries are presented to illustrate the utility and usefulness of the Web-based system as well as the convenience of data retrieval. The demonstration focuses on drilled shaft information for simplicity.

(1) According to loading type: For instance, the user intends to retrieve information on uplift load test cases under undrained loading condition. This information includes interpreted capacity from Chin's criterion and pre-analyzed data, such as undrained shear strength (s_u), adhesion factor alpha (α), parameter beta (β), and stress factor (k/k_o). In the event that the WBPLT system is unavailable, the database can only be accessed through SQL syntax, as shown in Fig. 9(a). This can be inconvenient and difficult for several users. However, this process is managed by the back-end system of WBPLT, and the SQL syntax does not need to be executed by the user. "Based on Loading Type" is selected from the main page, and then the page shown in Fig. 9(b) is displayed. "Uplift" and "Chin" are selected from the options on this page to generate a result, as shown in Fig. 10. The retrieved data include information on soil type, test date, longitude and latitude of the test site, pile length, pile diameter, and pre-analyzed parameters. The original load-displacement curve, load

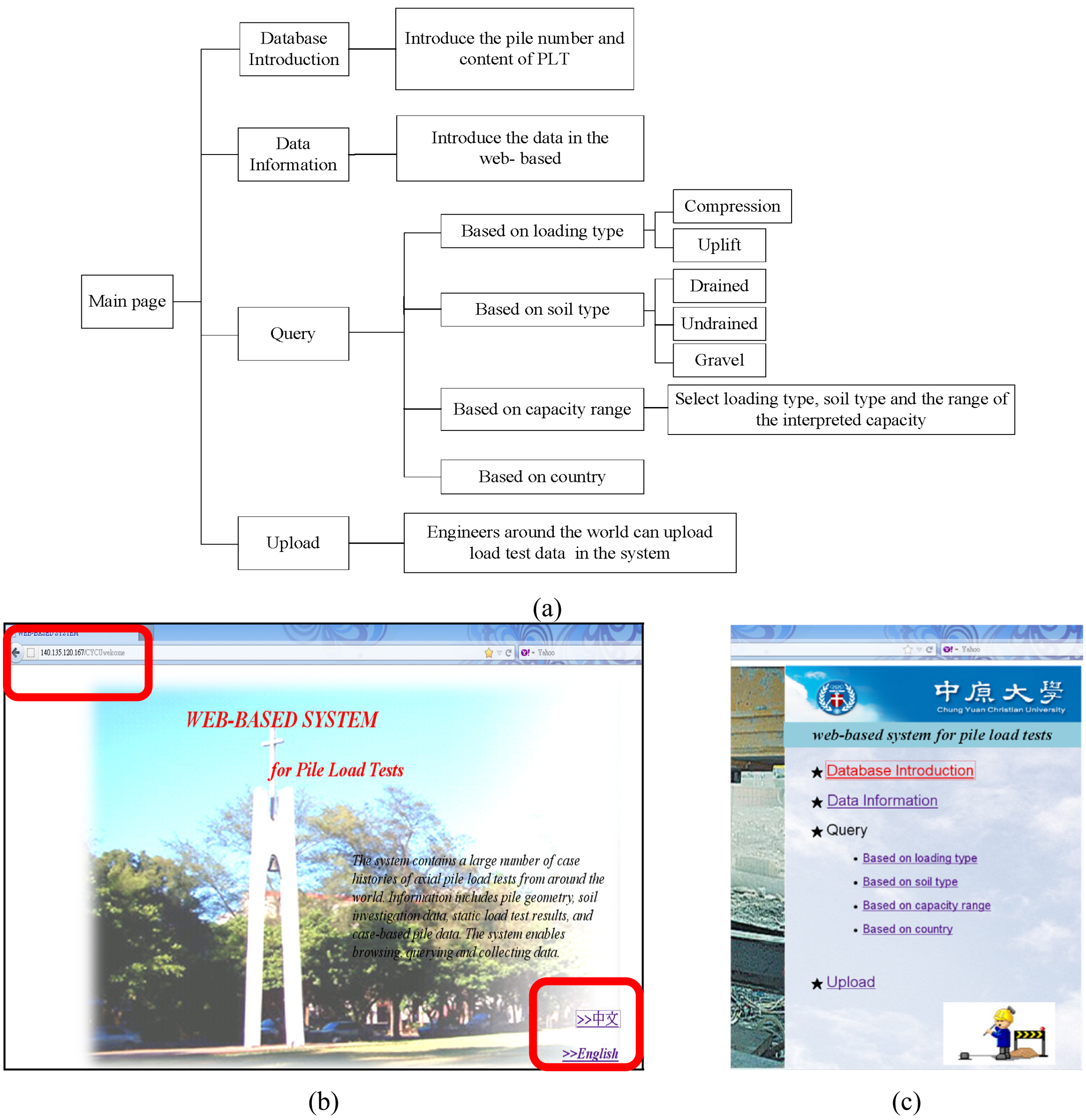
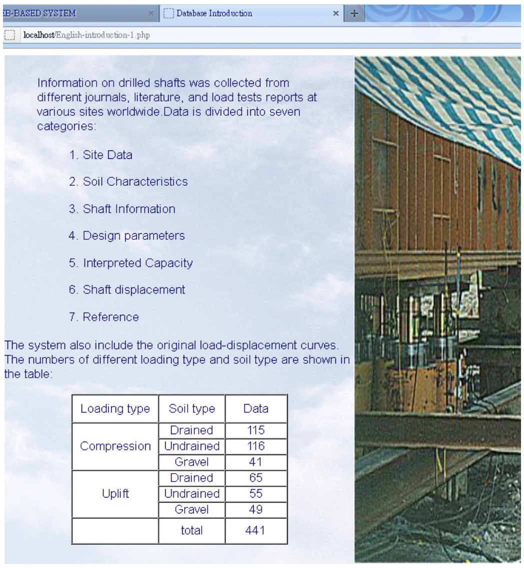


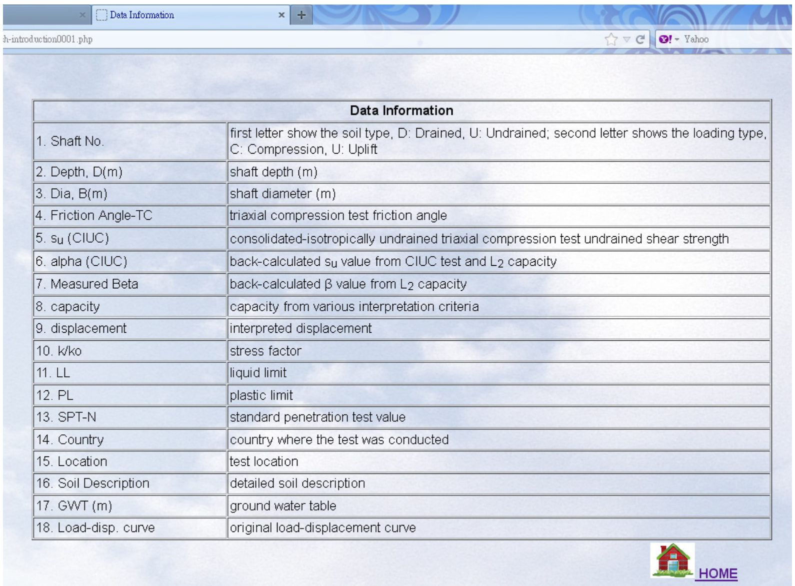
Fig. 7 WBPLT system: (a) schematic diagram; (b) home page; (c) main page

transfer curve, and soil profile can also be displayed by selecting “Fig” in Fig. 10. A sample original load-displacement curve from the database is shown in Fig. 11. The query for the selections “Based on Soil Type” and “Based on Country” from the main page follows the same process.

(2) According to capacity range: This query is detailed. “Based on a Capacity Range” is selected to display a screen for the selection of soil type, loading condition, interpretation criterion, and desired range of capacity. A capacity of less 5000 kN is selected. Fig. 12(a) shows the sample SQL query syntax for this condition. Fig. 12(b) shows the sample for the WBPLT system. The result of this query is shown in Fig. 13.



(a)



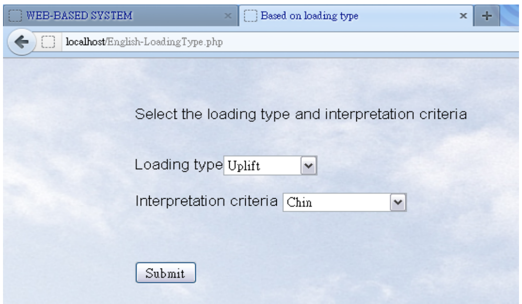
(b)

Fig. 8 WBPLT system: (a) introduction page; (b) information page

WBPLT allows engineers and designers to easily upload essential data to extend the purpose of the system. Qualified data are sorted and incorporated into the database together with other pile types and PLT information, thereby allowing the system to provide relevant information to the geotechnical community.

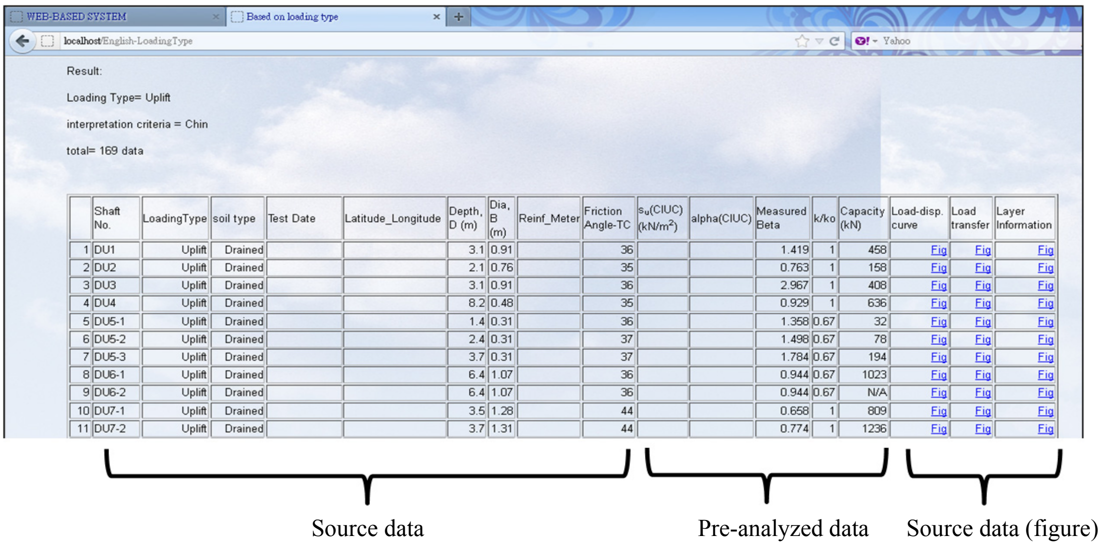
```sql
SELECT
shaft.`ShaftNo`,
shaft.`Depth_D_m`,
shaft.`Dia_B_m`,
shaft.`D/B`,
soil.`Soil_Type`,
soil.`Friction_Angle_TC`,
desparameter.`Su_CIUC`,
desparameter.`alpha_CIUC`,
desparameter.`Measured_Beta`,
capacity.`Chin`
.
.
.
FROM
soil_has_shaft
Inner Join soil ON soil.idSoil = soil_has_shaft.soil_idSoil
Inner Join site ON soil.site_idSite = site.idSite
Inner Join shaft ON soil_has_shaft.shaft_idShaft = shaft.idShaft AND shaft.site_idSite = site.idSite
Inner Join desparameter ON shaft.idShaft = desparameter.shaft_idShaft
Inner Join capacity ON capacity.shaft_idShaft = shaft.idShaft
Inner Join displacement ON capacity.Displacement_idDisplacement = displacement.idDisplacement

WHERE
shaft.`Loading_Type` = 'Uplift'
```

(a)



(b)

Fig. 9 (a) SQL syntax of query for loading type; (b) WBPLT system screenshot of query for loading type



	Shaft No.	LoadingType	soil type	Test Date	Latitude_Longitude	Depth, D (m)	Dia, B (m)	Reinf_Meter	Friction Angle-TC	s_u(CIUC) (kN/m^2)	alpha(CIUC)	Measured Beta	k/ko	Capacity (kN)	Load-disp. curve	Load transfer	Layer Information
1	DU1	Uplift	Drained			3.1	0.91		36			1.419	1	458	Fig	Fig	Fig
2	DU2	Uplift	Drained			2.1	0.76		35			0.763	1	158	Fig	Fig	Fig
3	DU3	Uplift	Drained			3.1	0.91		36			2.967	1	408	Fig	Fig	Fig
4	DU4	Uplift	Drained			8.2	0.48		35			0.929	1	636	Fig	Fig	Fig
5	DU5-1	Uplift	Drained			1.4	0.31		36			1.358	0.67	32	Fig	Fig	Fig
6	DU5-2	Uplift	Drained			2.4	0.31		37			1.498	0.67	78	Fig	Fig	Fig
7	DU5-3	Uplift	Drained			3.7	0.31		37			1.784	0.67	194	Fig	Fig	Fig
8	DU6-1	Uplift	Drained			6.4	1.07		36			0.944	0.67	1023	Fig	Fig	Fig
9	DU6-2	Uplift	Drained			6.4	1.07		36			0.944	0.67	N/A	Fig	Fig	Fig
10	DU7-1	Uplift	Drained			3.5	1.28		44			0.658	1	809	Fig	Fig	Fig
11	DU7-2	Uplift	Drained			3.7	1.31		44			0.774	1	1236	Fig	Fig	Fig

Fig. 10 Result for query according to loading type

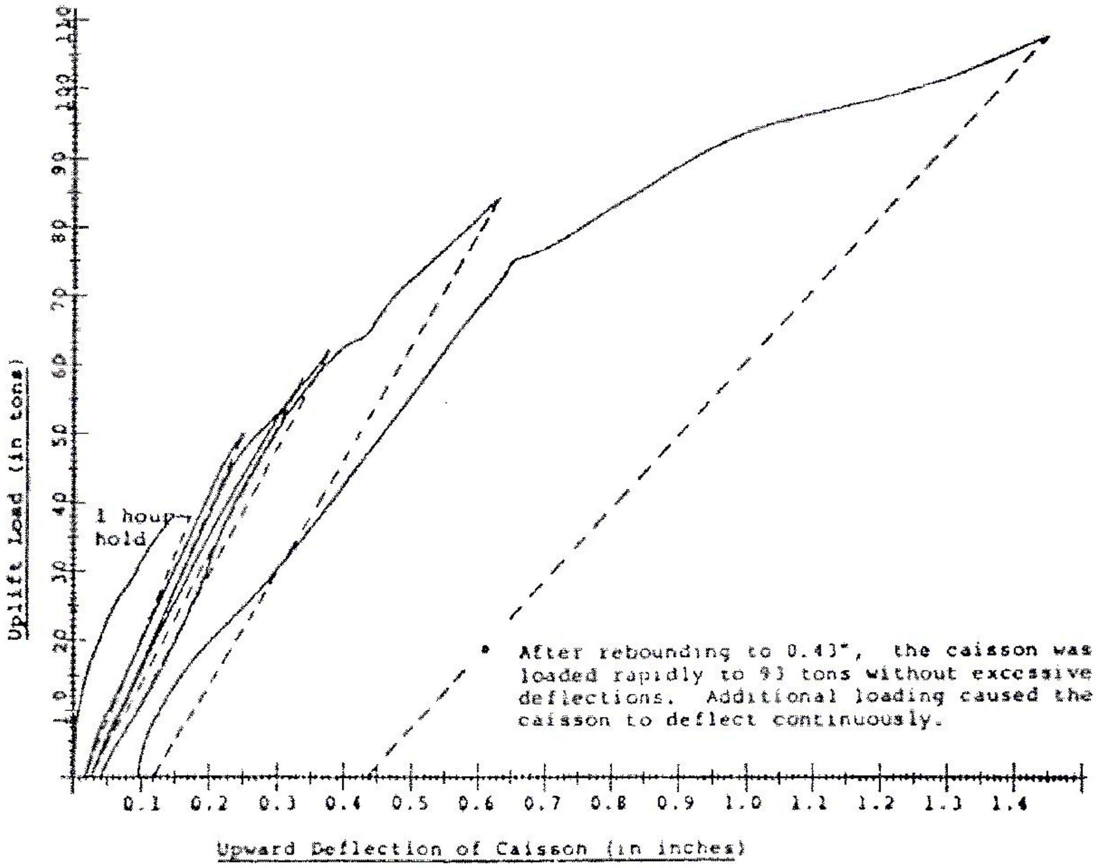
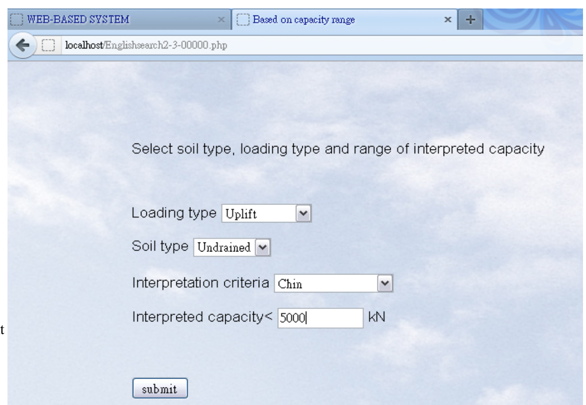


Fig. 11 WBPLT system data (original load-displacement curve, Stern *et al*. 1976)

```
SELECT
shaft.`ShaftNo`,
shaft.`Depth_D_m`,
shaft.`Dia_B_m`,
shaft.`D/B`,
shaft.`Loading_Type`,
soil.`Friction_Angle_TC`,
desparameter.`Su_CIUC`,
desparameter.`alpha_CIUC`,
desparameter.`Measured_Beta`,
capacity.`Chin`

FROM
soil_has_shaft
Inner Join soil ON soil.idSoil = soil_has_shaft.soil_idSoil
Inner Join site ON soil.site_idSite = site.idSite
Inner Join shaft ON soil_has_shaft.shaft_idShaft = shaft.idShaft AND shaft.site_idSite = site.idSite
Inner Join desparameter ON shaft.idShaft = desparameter.shaft_idShaft
Inner Join capacity ON capacity.shaft_idShaft = shaft.idShaft
Inner Join displacement ON capacity.Displacement_idDisplacement = displacement.idDisplacement

WHERE
soil.`Soil_Type` = 'Undrained' AND shaft.`Loading_Type` = 'Uplift'

HAVING capacity.`Chin` < '5000'
```



(a) (b)

Fig. 12 (a) SQL syntax of query for capacity range; (b) WBPLT system screenshot of query for capacity range

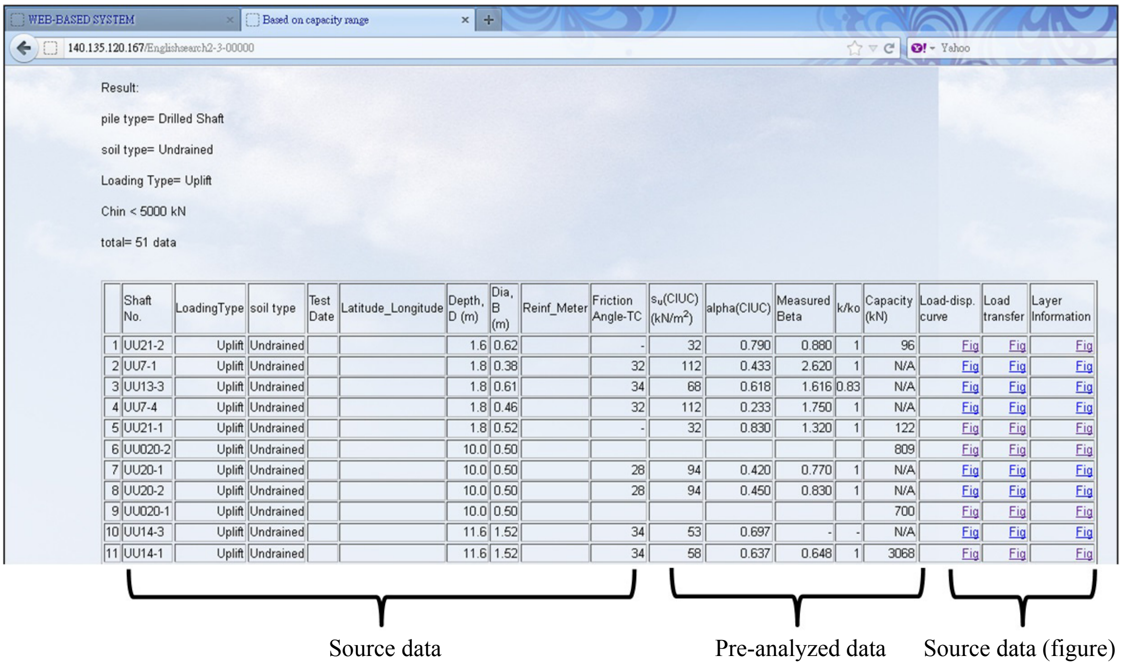


Fig. 13 Result for query according to capacity range

5. Conclusions

The development and execution of the proposed WBPLT system were clearly demonstrated in this study. Internet technology and a previously developed database were combined to maximize the efficiency of data retrieval and the usefulness of the system. The following conclusions were obtained based on the development process.

(1) Concept-based and object-oriented software design techniques were useful in integrating the PLT database and the Web-based system.

(2) A total of 673 case histories of pile load test are included in the database. The data consist of drilled shaft and driven precast concrete pile axial load tests in drained, undrained, and gravel loading conditions as well as pre-analyzed data and back-calculated design parameters.

(3) The WBPLT system architecture designed with UML revealed the good interaction and dynamic behavior of the system objects, namely, the client, presentation manager, controller, commander, reporter, and the PLT database.

(4) The Apache server functioned well as the main system, and the PHP language provided Web programming languages appropriately. The commander was successful in transforming requests into SQL language.

(5) Data retrieval from the PLT database content became efficient. WBPLT provides a

user-friendly interface that enables quick browsing, inexpensive querying, and easy collection of PLT information.

(6) Pile data holders around the world are encouraged to upload qualified data into the system to provide a centralized storage platform of information to the geotechnical community.

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