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Database of Dynamic Soil Properties for Most Iraq Soils

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Abstract

Earthquakes in Iraq has become a better knowledge after 1900 for amounts ranged from 2.7 to 7.2 ML within geographical boundary of the seismicity map of Iraq with a majority of crustal depth shocks ,there is a general characteristic and an increase in seismic activity in Iraq from the south to north and from west to east. Due to the location of Iraq on one side of the Arabian tectonic plate which earthquakes existed.The analysis of foundation vibrations and geotechnical earthquake engineering problems in civil engineering requires characterization of dynamic soil properties using geophysical methods. Dynamic structural analysis of the superstructures also requires knowledge of the dynamic response of the soil-structure, which, in turn relies on dynamics soil properties. The main objective in this study is to prepare a geotechnical and geophysics properties to build a database for different zones in Iraq (North, Eastern North, Western North, Middle, West, East, Western south, Eastern south and South) and different soils. From the data collected it has been observed that the average shear wave velocities were ranged from (274-1467) m/s in the North, (145-733) m/s in the Eastern North, (292-701) m/s in the Western North , (111-507) m/s in the Middle, (372-398) m/s in the East, (257,1164)m/s in the West, (198, 659) in the Western South, (111,420) in the Eastern South, (102,627) in the South of Iraqand The average compression wave velocities were ranged from (8077-2902) m/s in the North, (514-2606) m/s in the Eastern North, (714-1335) m/s in the Western North , (322-1544) m/s in the Middle, (976-1076) m/s in the East, (730,2835)m/s in the West, (198, 1659) in the Western South, (377,1167) in the Eastern South, (294,1811) in the South of Iraq.

Keywords: Earthquakes; seismic activity zone ; Iraq ; soil properties; compression wave velocities; ear wave velocities ; geotechnical earthquake engineering.

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1. Introduction

Iraq is located in a seismic zone is relatively active, and most areas of the country exposed to seismic activity in the past and may be exposed to seismic activity in the future; therefore it is very important to study and analyses the past-earthquakes, The northern zone depicts the highest seismic activity in the country, where the central and southern part of Iraq are characterized by moderate to low seismic activity [1].The engineering properties of the various strata of many geophysical and soil investigation reports for projects in Iraq, and the parameters are evaluated from field and laboratory tests results of the available geophysical and geotechnical investigation reports collected from different engineering resources. Dynamic soil characteristics could be identified from a different domain and / or laboratory investigations, They can also be evaluated using suitable empirical correlations established from earlier standard field and laboratory investigations carried on a particular type of soil [2], in this study the cross hole test and down hole test will be used to create database for the dynamic properties. These test methods are limited of the resolve of horizontally travel pressure (P) and shear (S) seismic waves in the test sites mainly composed of soil materials. Preferably test methods intended for use in important projects and included a higher quality of data that must be obtained.

2. Method to create a database work

2.1 Resource of Database

The engineering properties of the various strata of many geophysical and soil investigation reports for projects in Iraq, and the parameters are evaluated from field and laboratory tests results of the available geophysical and geotechnical investigation reports collected from different engineering resources Andrea Engineering Test Labs, National Center of Construction Laboratories and Research (NCCLR), AL-Ahmed Engineering Laboratories and from [3].

The available geotechnical and geophysics reports were collected from different fifty projects like gas power station, cement plant, multi-story buildings, thermal Power plant, water sewerage system, oil refinery and other projects from different locations of Iraq (North, Eastern North, Western North, Middle, East, West, Western south, Eastern south and South) as shown in Table (1) and Figure (1).

2.2 Soil Parameters Investigated for Iraq Soils

The soil parameters investigated for most Iraqi soil are evaluated and collected from different resources as mentioned before, these data were taken from geotechnical and geophysics investigation reports, the geotechnical reports had the soil parameters such as; γ_{wet} ,γ_{dry}, c, ϕ that evaluated by the field or laboratory tests, also these reports had different borehole logs which would description the soil types and gave the depth of water table. The geophysics reports which had the V_s, V_p, E_d, G_d ,v that been evaluated form the cross hole test and the down hole test . The geotechnical bore hole should be the same for the geophysics bore hole or might be different bore hole but they should be near to each other or collected either from the same borehole or two adjacent ones which have the same soil layers profile. These parameters with their standard units are listed below:

E : Young's modulus [kN/m^2]

υ : Poisson's ratio [-]

ϕ : Friction angle [°]

c : Cohesion [kN/m^2]

ψ :Dilatancy angle [°]

in addition to:

γ_{sat} : Saturated unit weight [kN/m^3]

γ_{unsat} : Saturated unit weight [kN/m^3]

Also the dynamic parameters which are collected from the geophysics reports are:

V_s: Shear wave velocity [m/s]

V_p: Compression wave velocity [m/s]

E_d: Dynamic modulus of elasticity [kN/m^2]

G_d: Dynamic shear modulus or (Rigidity) [kN/m^2]

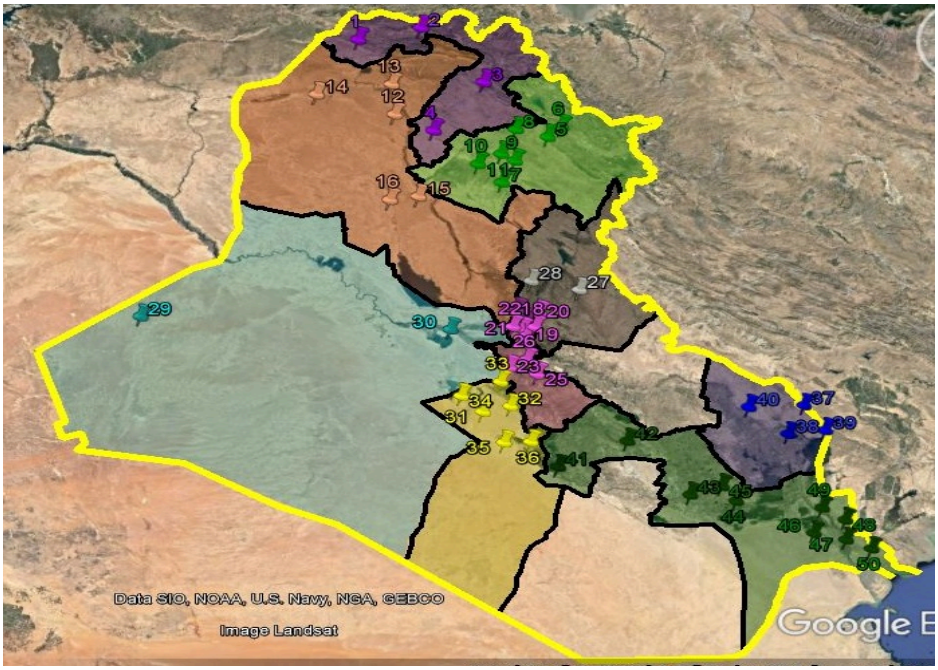

Figure 1: Map study of projects and locations in Iraq

Table 1: The available projects in some locations of Iraq with their site areas and symbols.

NO.	Zone	Site	Project	Site symbol	Map symbol
1	North	Dohuk	Dohuk Gas Power Station	N1	1
2		Dohuk	JabalKarah	N2	2
3		Irbil	Building of Electoral Office	N3	3
4		Irbil	North cement plant	N4	4
5	Eastern North	sulaymaniyah	Chamchamal Gas Power station	EN1	5
6		sulaymaniyah	Bazyan Combined Power Plant	EN2	6
7		Kirkuk	Imam zain Al-abden Bridge	EN3	7
8		Kirkuk	Kirkuk Depot.	EN4	8
9		Kirkuk	Kirkuk Cement Factory	EN5	9
10		Kirkuk	Kirkuk North Gas Company	EN6	10
11		Kirkuk	One June Depot	EN7	11
12	Western North	Mosul	Dry Gas Pipe Line for AL-Mosul power plant	WN1	12
13		Mosul	Al-Hadba Minaret	WN2	13
14		Mosul	Building of Independent Higher for Elections Commission	WN3	14
15		Salah Al-den	Baiji thermal Power plant	WN4	15
16		Salah Al-den	Salah Al-den thermal power plant	WN5	16
17	Middle	Baghdad	The Second production Line at East of Baghdad	M1	17
18		Baghdad	Housing Complex at Al-Rasheed camp	M2	18
19		Baghdad	Al-Dora power plant	M3	19
20		Baghdad	Basmayah Project	M4	20
21		Baghdad	Korean Embassy	M5	21
22		Baghdad	Al Qudus Gas Turbine Power Plant	M6	22
23		Baghdad	Al Karkh Pumping Station	M7	23
24		Baghdad	Al Taji Stadium	M8	24
25		Babylon	New pumping Station at Al-hindya Depot	M9	25
26		Babylon	Hilla Power Plant	M10	26
27	east	Diyala	Cultural and sport center	E1	27
28		Diyala	Al-Khalis housing complex	E2	28
29	west	Anbar	AKKAS Gas Field	W1	29
30		Anbar	Fallujah Sewerage System	W2	30
31	Western South	Karbala	Waste water treatment	WS1	31
32		Karbala	Karbala power plant	WS2	32
33		Karbala	Karbala Al Abbasia Sacred Shrine	WS3	33
34		Karbala	Karbala Cultural	WS4	34
35		Holy Najaf	Qasar Al-dur hotel	WS5	35
36		Holy Najaf	Al Najaf Al Salam Housing Complex	WS6	36
37	Eastern South	Missan	Al-amarah power plant	ES1	37
38		Missan	Halfaya Oil Field	ES2	38
39		Missan	Missan Oil Export Pipe Line	ES3	39
40		Missan	Al Amarah Water Intake Depot	ES4	40
41	South	Al Dewaniya	Al Dewaniya Refinery road	S1	41
42		Al Dewaniya	Al Dewaniya Pumping Station	S2	42
43		Al Nasiriya	Al Nasiriya Refinery	S3	43

44		Al Nasiriya	Al Nasiriya Water Intake	S4	**44**
45		Al Nasiriya	Al Nasiriya Oil Depot	S5	**45**
46		Al Basrah	New pumping station at Al-Sheiba	S6	**46**
47		Al Basrah	Al Sheiba Oil Refinery	S7	**47**
48		Al Basrah	Housing complex at Tannoma	S8	**48**
49		Al Basrah	Qarmat Ali Water treatment	S9	**49**
50		Al Basrah	Faw Depot Turbine	S10	**50**

2.3 Calculation for the soil parameters

As mentioned before the soil parameters such as; γ_{wet} ,γ_{dry} , c, ϕ are calculated from field tests or laboratory tests in geotechnical reports , and dynamic parameters such as; V_s and V_p are evaluated by geophysical investigations in which other parameters like; E, G and υ are calculated by mathematical equations relationships

$$\upsilon = \left[\frac{1/2(Vp/Vs)^2-1}{(Vp/Vs)^2-1}\right] \quad (1)$$

$$G = \rho V_s^2 \quad (2)$$

$$E_d = 2\,G\,(1+\upsilon) \quad (3)$$

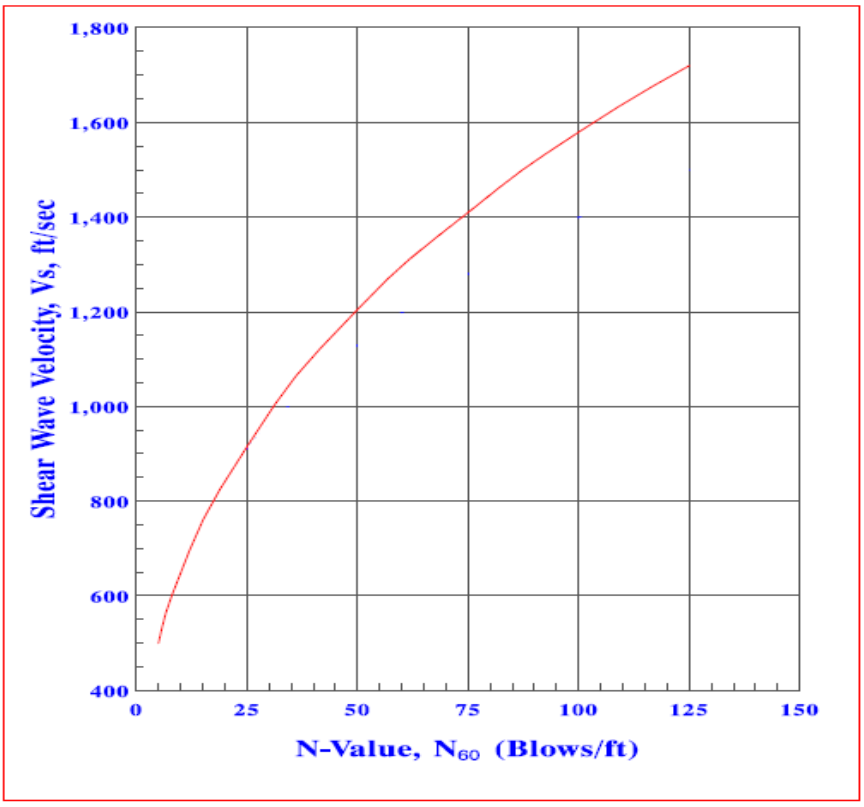

Figure 2: Relation Between Number of Blowes Per Foot in Standard Penetration Test and Velocity of Shear Waves (after department of defense handbook MIL-HDBK-1007/3, 1997).

3. The most important Field and laboratory test used in the study

3.1 Standard penetration test (SPT)

The Standard Penetration Test (SPT) is currently the most popular and economical means to obtain subsurface information.it used ina great variety of geotechnical exploration projects, in Iraq and throughout the world, one advantage of the SPT tests is that the drillers could collected samples For more classifications and laboratory investigations, the SPT test is Considered the in-situ test [4].Additional advantage to this simple and economical test is a wide range of researches that been doing it to link the empirically values of STP N with geotechnical design criterion Like the intensity the soil, , friction angles, the value of the shear strength, Young's modulus, shear modulus and settling shallow foundations**.** There aremost importantrelationships between SPT (N blows), relative density (Dr), and angle of internal friction (φ′) are given in Table (2) that used to determine the parameters of the soil. Figure (2)It shown he beneficial relationship between the values of N and velocities of shear wave.

Table 2: Relative density and consistency of soil (after Terzaghi& Peck, 1968 and Sanglerat,)

SPT(N)	Relative Density (Dr)	Description of Compactioness	Static cone Resistance (qc)	Angle of internal Friction φ′ degrees
4	0.2	Very loose	Under 2.0	Under 30
4-10	0.2 to 0.4	Loose	4.0 to 6.0	30 to 35
10-30	0.4to 0.6	Medium dense	6.0 to 12	35 to 40
30-50	0.6 to 0.8	Dense	12 to 20	40 to 45
50	0.8to 1	Very dense	Over 20	Over 45

3.2 Direct shear test

Direct shear test is used to evaluate the shear strength of the soils and the test is suitable for cohesionless soils. The mechanism of this test is by inserted deformation to a specimen at a controlled strain rate on or near a single shear plane determined by the configuration of the apparatus. In general two or three specimens are tested, and each specimens are under different loads and then determined the sear strength of the soil displacement, and strength properties such as Mohr strength envelopes [5].

3.3 Unconfined compression test

The unconfined compression test is used to calculate the strength of the cohesive soil in the undisturbed, remolded, or compacted condition, using strain-controlled application of the axial load.The unconfined compression test provided approximate values of strength of the clayey soil in term of stresses, in otherwise the test been inappropriate for dry sand or crumbly clays the soils would fall apart without some land of lateral confinement [6].

3.4Cross-hole seismictest

This test consists of two or three drilling boreholes side-by-side, typically with 10 foot (3 m) spacing. Cross-hole-seismic (CS) investigations are performed to provide information ondynamic soil and rockproperties for earthquakedesign analyses for structures, liquefaction potential studies, site development, anddynamic machine foundationdesign. The investigation determines shear andcompressional wave depthversus velocity profiles [7].

3.5 Down-hole seismictest

This test consist of a three component geophone lowered down and fixed against the soil wall using a clamping device so that a good coupling could be made between the instrument and the medium (Davis and Schultheiss, 1980).Down-hole seismic (DS) investigations are similar to the CS method, but require only one borehole to provide shear and compressional velocity wave profiles, down-hole seismic testing is one field test that is commonly used to determine compression-wave (P) and sear-wave (S) velocity profiles in geotechnical earthquake engineering investigations [7].

4. Site Soil Classification

Site soil conditions are important in determining Seismic Design Category and it classified according to to PISC (2013) and FEMA (2010), as shown in Tables (3) and (4) respectively, and the site soil is classified to type (A,B,C,D,E S_1or S_2) according to Eurocode 8 (2004) as shown in Table (5), site class is determined based on the average properties of the soil within 100 feet (30 meters) of the ground surface. Geotechnical engineers use a variety of parameters to characterize the engineering properties of these soils, including general soil classifications as to the type of soil, (e.g. hard rock, soft clay), the number of blows (N) needed to drive a standard penetration tool 1 foot into the soil using a standard hammer, the velocity (vs) at which shear waves travel through the material as measured by cross-hole and down-hole test.

Table 3: Site soil classification (after PISC, 2013).

Site Class Definition	V_s	N or N_{ch}	S_u
A Hard rock	>1500 m/s	_	_
B Rock	760 to 1500 m/s	_	_
C Very dense soil or soft rock	370 to 760 m/s	>50	>100kPa
D Hard soil	180 to 370 m/s	15 to 50	50 to 100 kPa

	<180 m/s	<15	<50kPa
E Soft clayey soil	Each side section thickness greater than 3m for soil profile of the following characteristics: - Plasticity Index PI > 20. - Water content w ≥ 40%. - Undrained shear strength S_u<25kPa		
F Soil types that require a special field assessment	1. Soil exposed to possibility of collapse. 2. Silt and/or clayey soil of high organic content. 3. Clayey soil of very high plasticity index. 4. Very thick clayey soil of weak /medium strength.		

Table 4: Site class and soil types (after FEMA, 2010).

Site Class	**General Description**	***V_s***	***N*** **Blows/foot**	***S_u***
A	Hard rock	>5000 ft/sec >1524 m/s	_	_
B	Rock	2500-5000 ft/sec 762-1524 m/s	_	_
C	Very dense soil and soft rock	1200-2500 ft/sec 365-762 m/s	>50	>2000 psf >95kPa
D	Stiff soil	600-1200 ft/sec 182-365 m/s	15 - 50	1000-2000 psf 47-95 kPa
E	Soft clay soil	<600 ft/sec <182 m/s	<15	<1000 psf <47kPa
F	Unstable soils	_	_	_

Table 5: Ground Types classification (after Eurocode 8, 2004).

Ground type	**Description of stratigraphic profile**	**Parameters**		
		$V_{s,30}$ **(m/ s)**	***N*, SPT (blows/30cm)**	c_u **(kPa)**
A	Rock or other rock-like geological formation including at most 5m of weaker material at the surface.	> 800	-	-
B	Deposits of very dense sand, gravel, or very stiff clay, at least several tens of metres in thickness, characterized by a gradual increase of mechanical properties with depth.	360-800	> 50	> 250
C	Deep deposits of dense or medium- dense sand, gravel or stiff clay with thickness from several tens to many hundreds of metres.	180-360	15 - 50	70-250
D	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil.	< 180	< l5	< 70
E	A soil profile consisting of a surface alluvium layer with *Vs* values of type Cor D and thickness varying between about 5 m and 20 m, underlain by stiffer material with *Vs* 800 m/s.			
S_1	Deposits consisting, or containing a layer at least 10m thick, of soft clays/silts with a high plasticity index (PI> 40) and high water content	< 100 (indicative)		10-20
S_2	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types A E or S_1			

4.1 Prepared the results for database

The geotechnical and geophysics reports are prepared and calculated from important projects in most zones and location of Iraqi soils and given as database arranged in Table (6). All the soils parameters are calculated included soil shear strength, friction angel, shear velocity, compression velocity etc...

Table 6: Soil properties in different locations and zones of Iraq.

No.	Site	Depth	Soil Type	WT	γ_{wet}	γ_{dry}	C	ϕ	V_p	V_s	E_d10^3	G_d10^3	ν
		(m)		(m)	kN/m)	kN/m^3	kN/m^2	(^{o})	m/s	m/s	kN/m^2	kN/m^2	-
1.	N_1	0-3	Brown silty clay with little fragment	NO W.T	18.4	15.3	32	17	992	302	123.69	86.64	0.463
		3-10	Dense grey gravel with sand to gravel with silt and sand(GP-Gm)		19	14.9	0	42	1445	468	266.1	211.23	0.46
2.	N_2	0-5	Reddish brown rock fragment of limestone with sand	>25	19.6	16.8	0	39	1623	832	954.23	451.38	0.345
		5-15	Light brown recrystallized limestone		20.3	18.6	0	43	2902	1467	1514.42	1035.7	0.369
No.	**Site**	**Depth**	**Soil Type**	**WT**	γ_{wet}	γ_{dry}	C	ϕ	V_p	V_s	E_d10^3	G_d10^3	ν
		(m)		(m)	kN/m)	kN/m^3	kN/m^2	(^{o})	m/s	m/s	kN/m^2	kN/m^2	-
3.	N3	0-4	Brown clayey silt with few sand,(CL-ML)	No W.T	20.4	17.3	62	19	687	274	391.3	142.5	0.405
		4-10	Brown silt/clay with few sand & trace of gravel,(CL-ML)		21.3	18.1	49	28	807	354	515.01	191.2	0.421
4.	N4	0-2	Fill material	3.6	-	-	-	-	864	260	174.8	121.4	0.44
		2-6	Brown silt/clay with few sand,(CL)		21.4	18.1	43	21	988	296	215.9	148.6	0.45
		6-10	Brown silt/clay with little sand& few gravel,(CL-ML)		21.2	17.8	35	34	1460	462	403.8	275.83	0.456
5.	EN1	0-4	Unknown	No	19.9	16.6	94	0	1745	262	212	144	0.4861

		4-15	Unknown	W.T	20.9	18.4	0	44	2606	576	1401	958	0.463
6.	**EN2**	0-5	Unknown	No W.T	19.4	17.6	81	3	1485	233	157.68	94.68	0.481
		5-10	Unknown		21.6	18.1	4	42	2313	384	333.76	283.48	0.4678
7.	**En3**	0-4	Stiff brown lean to fat CLAY (CL, CH)	3.9	19.7	16.8	55	0	535	219	89.89	45.3	0.401
		4-6	Medium brown silty Sand (SM)		19.6	17.2	21	33	679	301	543.71	101.45	0.385
		6-12	Dense grey gravel with sand to gravel with silt and sand(GP,Gp-Gm)		19.5	16.8	0	42	1384	733	479.18	198.34	0.392
8.	**EN4**	0-2	Brown silt with (ML)	2.9	19.4	17.7	5	37	360	145	124.2	44.25	0.403
		2-6	Stiff brown lean clay (CL)		17.3	15.8	80	0	514	212	606.65	98.44	0.392
		6-15	Stiff brown lean clay (CL)		19.4	17.5	21	39	1065	323	663.2	229.3	0.424
No.	**Site**	**Depth**	**Soil Type**	**WT**	γ_{wet}	γ_{dry}	C	ϕ	V_p	V_s	E_d10^3	G_d10^3	ν
		(m)		**(m)**	**kN/m)**	**kN/m^3**	**kN/m^2**	**(°)**	**m/s**	**m/s**	**kN/m^2**	**kN/m^2**	**-**
9.	**EN$_5$**	0-2.5	Stiff brown sandy SILT (ML)	>25	19	16.8	0	32	1125	225	290.15	98.09	0.479
		2.5-15	Very stiff to hard brown lean to fat CLAY (CL,CH)		20.6	18.2	227	0	1250	321	634.86	216.38	0.467
		15-20	Very dense silty GRAVEL with SAND (GM)		20.6	18.2	0	42	2500	476	1409.8	475.9	0.481
10.	**EN$_6$**	0-10	Stiff to very stiff brown lean or fat CLAY (CL,CH)	2.6	21.0	18.1	120	0	1541	304	585.82	197.91	0.48
11.	**EN$_7$**	0-10	Very stiff to hard brown lean CLAY (CL)	3.8	20.1	17	130	0	1250	312	585.43	199.53	0.467
12	**WN**	0-15	Very Stiff to hard	2.8	19	17.3	65	0	1335	459	602.1	210.31	0.413

	1		moderately gypseous, brown lean to fat clay (CL,CH)										
13	WN 2	0-7.5	Dark brown sand silt with rock fragments	>25	18.3	16	0	37	773	319	542.6	189.3	0.432
		7.5-20	Brown sand gravel		17.8	15.3	0	42	1113	348	600.3	202.5	0.416
14.	WN 3	0-4	Loose brown silt or gravelly silt with sand(ML)	2.3	20.1	17.5	0	34	978	303	568.42	159.56	0.433
		4-15	Medium dense to very dense grey silty gravel with sand (GM,Gp)		19.4	16.3	0	38	1057	362	584.6	217.2	0.424
No.	**Site**	**Depth**	**Soil Type**	**WT**	γ_{wet}	γ_{dry}	C	ϕ	V_p	V_s	E_d10^3	G_d10^3	ν
		(m)		**(m)**	**kN/m)**	**kN/m^3**	**kN/m^2**	**(^{o})**	**m/s**	**m/s**	**kN/m^2**	**kN/m^2**	**-**
15.	WN_4	0-2	Grey gravel with silt sometimes with sand(GM)	No W.t	18.3	16.8	0	36	714	292	213.45	133.51	0.39
15.	WN_4	2-5	Medium stiff to hard brown lean clay sometimes with sand and gravel to silt(CL,ML)	No W.t	20.1	15.3	46	34	1055	346	285.42	198.4	0.421
		5-10	Dense to very dense grey gravel with silt and sand to gravel		17.8	16.1	0	43	1335	606	612.83	264.61	0.406
16.	WN5	0-4	Highly gypseous silty sand to sandy silt with little gravel	16	18.4	15.9	0	37	942	451	578.65	249.98	0.374
		4-20	Silty sand with		19	14.8	0	41	1373	701	845.6	321.65	0.396

			gravel to sand with gravel										
17.	**M1**	0-10	Stiff to very stiff brown to green slightly,gypseousmarly lean to fat clay and silt clay (CL,CH,CL-ML)	2.1	18.7	14.8	76	12	544	186	187.1	64.84	0.446
		10-16	Loose to medium grey to green silty sand (SM)		20	16.3	0	36	736	258	381.9	140.42	0.433
18.	**M2**	0-8	Medium to stiff to very stiff brown lean clay (CL)	2.6	20.1	17	125	0	820	265	414.42	144.1	0.438
		8-15	Loose to dense grey silty sand to clayey silty sand		19.1	15.5	0	36	1150	395	621.54	188.84	0.44
No.	**Site**	**Depth**	**Soil Type**	**WT**	γ_{wet}	γ_{dry}	C	ϕ	V_p	V_s	E_d10^3	G_d10^3	ν
		(m)		**(m)**	**kN/m)**	**kN/m^3**	**kN/m^2**	**(^{o})**	**m/s**	**m/s**	**kN/m^2**	**kN/m^2**	**-**
19.	**M3**	0-10	Soft to stiff brown lean or fat clay or silt sometimes lean clay with sand to sandy silt (CL,CH,ML)	0.8	18.7	14.9	52	12	443	153	156.53	56.9	0.43
		10-18	very dense grey silt sand or clayey sand (SM,SC)		19	14	0	39	769	215	259.33	107.2	0.445
20.	**M_4**	0-10	Stiff to very stiff brown lean clay (CL)	1.55	19.78	17.43	180	0	761	298	538.8	191.5	0.408
		10-15	Stiff to very stiff grey to brown to black lean clay sometimes with sand		20.2	17.1	68	16	1113	428	995.34	373.2	0.415

			(CL)										
		15-20	Medium grey silty sand (SM)		20.89	17.02	0	34	1351	507	1388.65	511.6	0.417
21.	**M_5**	0-10	Medium stiff to hard brown sometimes to grey lean fat clay (CL)	16	19.9	16.5	85	0	615	240	257.89	123.37	0.441
		10-15	Loose to medium grey silty sand (SM)		18.4	15.6	0	38	1191	430	672.84	280.17	0.454
22.	**M6**	0-1	Brown to grey clayey silt to sandy silt with filling materials, organic to salts (ML)	1.3	19.00	15.8	28.7	0	322	140	105	37.96	0.383
		1-15	Brown to Grey Silty CLAY to Clayey Silt (ML,CL,CH)		18.88	14.7	31.5	0	776	219	268.9	92.34	0.456
No.	**Site**	**Depth**	**Soil Type**	**WT**	**γ_{wet}**	**γ_{dry}**	***C***	**ϕ**	**V_p**	**V_s**	**E_d10^3**	**G_d10^3**	***v***
		(m)		**(m)**	**kN/m)**	**kN/m^3**	**kN/m^2**	**(^{o})**	**m/s**	**m/s**	**kN/m^2**	**kN/m^2**	**-**
22.	**M6**	15-20	Grey Sand to silty or clayey SAND to Gravilly SAND		22.31	17.04	0	38	1544	408	1107.4	378.73	0.462
23.	**M7**	0-6	Medium stiff to stiff brown fat CLAY (CH)		19.8	15.8	50	0	641	189	209.16	72.13	0.45
		6-12	Very stiff brown lean CLAY (CL)	0.6	19.0	14.5	100	0	675	248	338.44	119.17	0.42
		12-15	Medium to dense silty clayey SAND to silty SAND		19.0	15.0	0	37	750	225	284.46	98.09	0.45
24.	**M8**	0-7.5	Stiff to very stiff brown lean to fat CLAY(CL-CH)	2.2	19.8	17.1	65	10	841	165	162.7	54.97	0.48
		7.5-12	Medium to very		19.0	16.5	0	38	1025	279	440.3	150.8	0.46

			dense grey silty SAND (SM)										
25.	**M_9**	0-5	Very soft to stiff brown lean to fat CLAY sand(CL,CH)	1.41	21.26	17.85	90	0	735	260	294.46	145.35	0.397
		5-15	losse to dense grey silty SAND(SM)		18.6	15.4	0	38	1503	369	1107.4	242.5	0.403
26.	**M_{10}**	0-2.4	Grayish sandy silty CLAY soil, medium consistency	1.5	16.18	14.5	144	0	306	111	57.9	20.33	0.424
		2.4-15	Grayish silty sand soil, medium dense		18.44	16.5	0	38	450	183	176.33	62.98	0.4
27.	**E_1**	0-10	Very stiff to hard brown to grisg brown marl lean CLAY (CL)	1.72	21.1	18.3	83	0	976	372	722.86	362.2	0.398
No.	**Site**	**Depth**	**Soil Type**	**WT**	**γ_{wet}**	**γ_{dry}**	**C**	**ϕ**	**V_p**	**V_s**	**E_d10^3**	**G_d10^3**	**ν**
		(m)		**(m)**	**kN/m)**	**kN/m^3**	**kN/m^2**	**(^{o})**	**m/s**	**m/s**	**kN/m^2**	**kN/m^2**	**-**
28.	**E_2**	0-15	Stiff to hard brown CLAY (CL)	1.46	20.3	17.1	76	0	1076	398	762.85	331.95	0.424
29	**W_1**	0-5	Marly lime ,Color – Off white to light Pink, Low hardness	No. W.T	18.7	17.5	9	52	1220	817.8	3029.94	907.1	0.284
		5-12	Limestone, color off White to light gray, High Hardness, Contains Fossils.		18.8	16	1	49	2216	1164	7159.36	3058.7	0.317
		12-15	Lime Mud, Chalky lime,		19.8	15.2	0	51	2835	1203	9396.95	3370.1	0.393
30.	**W_2**	**0-5**	Stiff to very stiff brown lean	1.75	20.4	17.07	120	0	730	257	283.76	135.85	0.421

			CLAY(CL)										
		5-10	Loose to dense grey to dark grey silty SAND and clayey silty SAND sometimes with gravel(SM,SC-SM)		18.2	15.2	0	33	1513	379	1147.4	282.34	0.433
31.	**WS_1**	**0-5**	Stiff brown to green lean CLAY (CL)		19.5	15.6	77	0	688	198	223.14	72.87	0.458
		5-9	Loose to medium brown to grey silty SAND (SW-SM)	1.2	18.4	14.8	0	33	948	265	341.37	152.91	0.46
		9-15	Very dense grey silty SAND (SW)		19.1	15.3	0	36	1370	497	1138.75	927.84	0.433
No.	**Site**	**Depth**	**Soil Type**	**WT**	**γ_{wet}**	**γ_{dry}**	**C**	**ϕ**	**V_p**	**V_s**	**E_d10^3**	**G_d10^3**	**ν**
		(m)		**(m)**	**kN/m)**	**kN/m^3**	**kN/m^2**	**(^{o})**	**m/s**	**m/s**	**kN/m^2**	**kN/m^2**	**-**
32	**WS_2**	**0-18**	Loose to very dense off white yellow, light brown to grey sometimes moderately gypseous silty SAND or SAND with silt or SAND (SM,SP-SM,SP)	NO W.T	19.6	17.93	0	38	986	417	1071.63	681.97	0.405
33.	**WS 3**	**0-10.5**	Stiff brown silty to moderatlygypseous fat CLAY (CH)	1.5	18.5	14.7	100	0	1416	312	541.76	183.65	0.475
		10.5-14	Very loose to medium green to yellow marly SAND		19	17.1	0	50	1474	289	479	161.83	0.48

			(SM)										
34.	**WS_4**	**0-4.5**	Dense white to yellow slightly to moderately gypseous SAND with silt to silty SAND with gravel (SP,SM)	0.8	18.8	18	0	37	1433	284	457.0	154.6	0.478
		4.5-12	Dense to very dense white to yellow SAND with silt (SP,SM)		19.4	18	0	35	1733	550	1727.2	598.46	0.443
		12-22	Very dense white to yellow SAND with silt to silty SAND (SP,SM)		19.4	18	0	35	1650	563	1801	627.1	0.436
No.	**Site**	**Depth**	**Soil Type**	**WT**	**γ_{wet}**	**γ_{dry}**	**C**	**ϕ**	**V_p**	**V_s**	**E_d10^3**	**G_d10^3**	**ν**
		(m)		**(m)**	**kN/m)**	**kN/m^3**	**kN/m^2**	**(^{o})**	**m/s**	**m/s**	**kN/m^2**	**kN/m^2**	**-**
35.	**WS_5**	**0-10**	Very loose grading to very dense slightly to moderately gypseous SAND (SM) or SAND with silt(SP-SM)	2.1	17.5	14.9	0	41	1613	618	742.49	995.35	0.418
36.	**WS6**	**0-1.2**	Medium- dense light brown slightly gypseous silty SAND (SM)	0.9	19.1	17	0	43	805	268	458.15	159.3	0.438
		1.2-7	Medium- dense to very dense light brown SAND (SP)		19.5	18	0	40	1450	557	1743.5	616.95	0.413
		7-10	Very dense light brown silty SAND (SM)		19.6	18	0	39	1812	659	2472.2	868.03	0.424

37.	**ES_1**	**0-6**	Stiff to very stiff brown to green sandy lean to fat CLAY (CL,CH)	0.41	19.2	14.8	53	4	451	111	75.41	35.87	0.464
		6-14	Loose grey silty SAND (SM)		20.45	17.8	0	36	605	152	139.28	57.49	0.457
		14-20	Stiff to very stiff brown to green fat CLAY (CH)		19.9	15.6	63	0	690	211	265.49	98.97	0.429
38.	**ES_2**	**0-5**	Medium stiff to stiff brown lean to fat CLAY (CL,CH)	0.6	18.0	14.6	65	0	377	131	90.15	31.5	0.431
		5-8	Stiff brown lean to fat CLAY (CL,CH)		19.5	15.8	60	0	604	250	347.98	124.28	0.4
		8-17	Stiff brown lean CLAY (CL)		20.8	15.9	60	8	1362	420	1082.8	374.17	0.447
No.	**Site**	**Depth**	**Soil Type**	**WT**	**γ_{wet}**	**γ_{dry}**	**C**	**ϕ**	**V_p**	**V_s**	**E_d10^3**	**G_d10^3**	**ν**
		(m)		**(m)**	**kN/m)**	**kN/m^3**	**kN/m^2**	**(^{o})**	**m/s**	**m/s**	**kN/m^2**	**kN/m^2**	**-**
39.	**ES_3**	**0-9**	Medium stiff to stiff brown lean to fat CLAY (CL,CH)	0.6	19.7	15.7	80	0	696	179	188.5	64.37	0.464
		9-18	Stiff brown lean CLAY (CL)		20.9	16.1	60	0	1167	380	886.78	307.76	0.44
40.	**ES_4**	**0-7.5**	Medium stiff to stiff brown lean to fat CLAY (CL,CH)	0.6	19.5	15.1	80	0	500	176	175.96	61.57	0.429
		7.5-9	Loose grey silty SAND		19.5	15.7	0	29	600	200	228.51	79.51	0.437
		9-10	Stiff brown lean CLAY (CL)		19.5	15.7	60	8	600	250	346.6	124.23	0.395
41.	**S_1**	**0-5**	Stiff to very stiff brown to green sandy lean to fat	0.3	19.6	15	42	8	685	225	161.65	56.58	0.424

			CLAY (CL,CH)										
		5-6.5	Loose grey silty SAND (SM)		20.7	17.2	0	33	814	243	189.02	65.19	0.451
		6.5-10	Stiff to very stiff brown to green fat CLAY (CH)		19.3	14.9	65	0	1224	333	233.4	146.8	0.466
42.	**S_2**	**0-1.5**	Brown lean CLAY(CL)		18.5	14.4	94	0	625	188	193.28	66.65	0.450
		1.5-2	loose grey silty SAND layer (SM)	0.3	20.0	15.0	0	30	909	185	213.45	72.21	0.478
		2-10	Medium stiff to very stiff brown to green marly lean to fat CLAY (CL,CH)		19.3	14.7	60	5	909	200	232.17	78.73	0.475
No.	**Site**	**Depth**	**Soil Type**	**WT**	**γ_{wet}**	**γ_{dry}**	***C***	**ϕ**	**V_p**	**V_s**	**E_d10^3**	**G_d10^3**	***v***
		(m)		**(m)**	**kN/m)**	**kN/m^3**	**kN/m^2**	**(°)**	**m/s**	**m/s**	**kN/m^2**	**kN/m^2**	**-**
.43	**S_3**	**0-8**	Medium stiff to hard brown or grey or dark grey lean to fat CLAY sometimes with sand to sandy lean CLAY or silt or sandy SILT(CL,CH)	1.2	19.1	15.8	78	0	646	185	198.82	68.72	0.458
.43	**S_3**	**8-15**	Dense to very dense grey or dark grey or brown silty SAND ot silty clayey SAND or SAND with silt (SM,SC-SM,SP-SM)	1.2	17.7	14.6	0	40	1094	321	427.66	198.94	0.464

44.	**S4**	**0-12**	Soft to medium black, brown, green light, green lean to fat CLAY (CL,CH)	1.7	19.5	15.2	90	3	434	110	70.54	24.06	0.466
		12-14	Loose grey silty SAND (SM)		20.8	18	0	41	500	145	129.7	44.6	0.454
		14-15	Very stiff brown, green lean CLAY(CL)		20.8	17	191	0	600	166	170.56	58.45	0.459
45.	**S5**	**0-4**	Very stiff brown lean CLAY (CL)	4.1	19.07	15.1	34	0	600	200	223.45	77.75	0.437
		4-10	Stiff to hard brown lean to fat CLAY (CL,CH)		19.93	15	112	0	750	240	337.6	117.1	0.442
No.	**Site**	**Depth**	**Soil Type**	**WT**	**γ_{wet}**	**γ_{dry}**	**C**	**ϕ**	**V_p**	**V_s**	**E_d10^3**	**G_d10^3**	**ν**
		(m)		**(m)**	**kN/m)**	**kN/m^3**	**kN/m^2**	**(^{o})**	**m/s**	**m/s**	**kN/m^2**	**kN/m^2**	**-**
46.	**S6**	**0-3**	Medium light brown gypseous soil	1.6	20.3	16.8	0	35	803	329	780.35	258.63	0.397
		3-10	Medium to very dense light brown to grey slightly to highly gypseous silty SAND or SAND with silt or SAND (SM,SP-SM,SP)		18.9	16.01	0	34	1811	627	1797.46	737.98	0.446
47.	**S7**	**0-3.7**	Grey gypseous SAND (SM)	1.8	18.18	16.1	5.33	39	566	230	244.6	87.29	0.401
		3.7-15	Grey gypseous silty SAND (SM)		19.16	15.3	8.4	40	1404	365	682.52	233.14	0.463
48.	**S8**	**0-6**	Very soft to stiff lean CLAY (CL)	5	21.1	16.4	60	0	434	166	168.06	59.47	0.412
		6-15	Very loose grey		19	15.3	0	37	510	194	207.35	88.4	0.417

			clayey silty SAND (SC-SM)										
49.	**S9**	**0-6**	Medium stiff to stiff brown to fat CLAY (CL,CH)	1.1	19.7	15.7	80	0	294	117	73.98	49.12	0.401
49	**S9**	**6-12**	Stiff brown lean CLAY (CL)	1.1	20.9	16.1	60	0	381	198	145.3	83.77	0.427
50.	**S10**	**0-10**	Very soft to very stiff brown lean or fat CLAY(CL,CH)		18.37	13.92	40	0	550	138	104.6	35.7	0.466
		10-13	Grey silty SAND (SM)	1.0	19.63	15.54	0	37	334	103	61.8	21.23	0.455
		13-15	Very soft to very stiff brown lean CLAY (CL)		20.02	16.03	48	0	450	102	62.57	21.24	0.473

4.2 Seismic site soil classification

The classification of sites soil are used to determine thecategories of seismic designed and all the seismic sites soils and it classified according to PISC (2013) and FEMA (2010), , and the site soil is classified to type (A,B,C,D,E S_1or S_2) according to Eurocode 8 (2004) and this classification are depended on one of the three methods:

- The number of blows (N) needed to drive a standard penetration tool 1 foot into the soil using a standard hammer
- The shear resistance of the soil (su) as measured using standard laboratory test procedures.
- the velocity (vs) at which shear waves travel through the material as measured by down and cross hole tests or computed in accordance with the following expression:
- $V_{s,30} = \frac{H}{\sum_{i=1,N} \frac{h_i}{v_i}}$ (4)

The sitesclass are determined based on the average properties of the soil within 65 feet (20 meters) from the ground surface level. The sites soil classified by a geotechnical engineers by using the variety of the parameters (e.g. hard rock, soft clay) and to characterize the soils properties.

4.3 Seismic site soil classification of Iraqi Soils

Iraqi site soils classified according to the Preliminary draft of Iraqi Seismic Code, FEMA, 2010 and Eurocode 8, 2004 as shown in the Table (7) and the classification depended on the shear wave velocity which are calculated by using cross and down-hole test from depth 10 to 20 m.

Table 7: Iraq site soil classification.

No.	Site	Max. depth of Geophysical Investigations (m)	V_s (m/s)	PISC 2013 and FEMA 2010	Eurocode 8 2004
1	N_1	10	369	D	C
2	N_2	15	974	B	A
3	N_3	10	312	D	C
4	N_4	15	298	D	C
5	EN_1	15	821	B	A
6	EN_2	10	324	D	C
7	EN_3	12	357	D	C
8	EN_4	15	325	D	C
9	EN_5	20	330	D	C
No.	**Site**	**Max. depth of Geophysical Investigations (m)**	**V_s (m/s)**	**PISC 2013 and FEMA 2010**	**Eurocode 8 2004**
10	EN_6	10	304	D	C
11	EN_7	10	367	D	B
12	WN1	15	328	D	C
13	WN2	20	642	D	B
14	WN3	15	333	D	C
15	WN4	10	301	D	C
16	WN5	20	617	D	B
17	M_1	16	178	E	D
18	M_2	15	298	D	C
19	M_3	18	175	E	D
20	M_4	20	196	D	C
21	M_5	15	172	E	D
22	M_6	20	240	D	C
23	M_7	15	217	D	C
24	M_8	12	190	D	C
25	M_9	15	254	D	C
26	M_{10}	16	198	D	C
27	E1	10	302	D	C

28	E2	15	322	D	C
29	W_1	15	923	B	A
30	W_1	10	276	D	C
31	WS_1	15	289	D	C
32	WS_2	18	429	D	B
33	WS_3	14	306	D	C
34	WS_4	22	466	C	B
35	WS_5	10	543	C	B
36	WS_6	10	514	C	B
37	ES_1	20	216	D	C
38	ES_2	17	237	D	C
39	ES_3	18	243	D	C
40	ES_4	10	185	D	C
41	S_1	10	250	D	C
No.	**Site**	**Max. depth of Geophysical Investigations (m)**	***V_s (m/s)***	**PISC 2013 and FEMA 2010**	**Eurocode 8 2004**
42	S_2	10	198	D	C
43	S_3	15	205	D	C
44	S_4	15	116	E	D
45	S_5	10	222	D	C
46	S_6	10	460	C	B
47	S_7	15	349	D	C
48	S_8	15	169	E	D
49	S_9	12	115	E	D
50	S_{10}	15	124	E	D

5. Conclusions from the collected database

The following conclusions from the collected database maybe summarize:

1- The geophysics and geotechnical database (V_p ,V_s , γ_{wet} ,γ_{dry} , c) are evaluated as well as, the corresponding average dynamic Young's and shear modulus of soil layers for seismic active zones in Iraq to be used as input data for simulation of behavior of shallow foundation in Mohr-Coulomb model under earthquake excitation using **PLAXIS 3D 2013**program.

2- The average compression wave velocities were ranged from (877-2902) m/s in the North, (514-2606)

m/s in the Eastern North, (714-1335) m/s in the Western North , (322-1544) m/s in the Middle, (976-1076) m/s in the East, (730,2835)m/s in the West, (198, 1659) in the Western South, (377,1167) in the Eastern South, (294,1811) in the South of Iraq.

3- The average shear wave velocities were ranged from (274-1467) m/s in the North, (145-733) m/s in the Eastern North, (292-701) m/s in the Western North , (111-507) m/s in the Middle, (372-398) m/s in the East, (257,1164)m/s in the West, (198, 659) in the Western South, (111,420) in the Eastern South, (102,627) in the South of Iraq.

4- Modulus of Elasticity was ranged from (123.69-1514.42) m/s in the North, (89.89-1409.8) m/s in the Eastern North, (213.45-845.6) m/s in the Western North , (57.9-1388.65) m/s in the Middle, (722.86-762.85) m/s in the East, (283.76,9396.95)m/s in the West, (223.14, 2472.2) in the Western South, (75.41,1082.8) in the Eastern South, (61.8,1797.46) in the South of Iraq.

5- Shear modulus of elasticity was ranged from(86.64-1035.7) m/s in the North, (44.25-958) m/s in the Eastern North, (133.51-321.65) m/s in the Western North , (20.33-378.73) m/s in the Middle, (331.95-362.2) m/s in the East, (135.85,3370.1)m/s in the West, (72.87, 995.35) in the Western South, (31.5,374.17) in the Eastern South, (21.23,737.98) in the South of Iraq.

6- Iraq sites soils were classified as types (E,D,C and B)according to PISC (2013) and FEMA (2010) and classified as types (D, C ,B and A) according to Eurocode 8 (2004).Thus Iraq soils are ranging between; Very dense soil, soft rock or gravel for WS_1 and $WS_3$for the western south zone and hard soil (rock) for N_2 and W_1 for north and west zones sites, to soft clayey soil or loose-to-medium cohesionless soil for M_1 and M_3 sites of the Middle zone and S_4, $S_{8,}$ $S_9$and S10 sites of South zone in Iraq.

7- The data base shows that the values of compression and shear velocities are highest in rock soil and the sandy soils are higher than in clayey soils and the highest difference in shear and compression wave velocities for the different successive soil layers. Interface of different soil layers as the compression or shear wave passes from sandy soil of higher wave velocity to the clayey soil of the lower wave velocity.

References

[1]. Alsinawi, S.A. & Al-Ridha, N (1988) "Microseismicity of Iraq 1974-1982" ,Iraqi Jour. Science, Vol 29,No.1&2, pp 91-108.

[2]. Hardin, B.O. &Drnevich, V.P. (1972a) “Shear modulus and damping in soils", Measurement and parameter effects”. Journal of Soil Mechanics and Foundation.

[3]. Qassun S. M. Shafiqu & Ruba H. Sa'ur (2017) "Data base of some Iraqi Soil", Iraq Journal of Engineering, Vol 22 July 2016, NO. 7

[4]. ASTM D 1586 – 99, Penetration Test and Split-Barrel Sampling of Soils.

[5]. ASTM D 3080 / D3080M-98, Direct Shear Test

[6]. ASTM D 2166-00, Unconfined Compressive Strength of Cohesive Soil.

[7]. Doug Crice (2002) "Borehole Shear-Wave Surveys for Engineering Site Investigations" Geostuff 19623 ViaEscuela Drive Saratoga, CA 95070 USA.

[8]. Department of Defense Handbook, 1997, Soil Dynamics and Special Design Aspects, MIL-HDBK-1007/3.

[9]. FEMA, 2010, Earthquake-Resistant Design Concepts, an Introduction to the NEHRP Recommended Seismic Provisions for New Buildings and Other Structures, P-749 / Dec. 2010.

[10]. Eurocode 8, 2004, Design of Structures for Earthquake Resistance, Part 1 , The European Union Per Regulation 305/2011, Directive 98/34/EC, Directive 2004/18/EC.

[11]. The Preliminary Draft of Iraqi Seismic Code, 303, submitted to Central Organization for Standardization and Quality Control COSQC, 2013.