Seismic response of reinforced concrete buildings as predicated by the draft of Libyan standard (DSLS-1977) and (IBC-2009)

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Abstract

The draft of suggested Libyan Standard (DSLS-1977) is the only code of practice for designing and construction of earthquake resistant buildings in Libya, was first proposed by the Ministry of Housing in 1977, it is still used by Libyan engineers and several other foreign firms operating in Libya. The draft is suffering from many limitations and shortcomings, it has not been subjected to any development for a long period to be consistent with modern codes. DSLS-1977 divided Libya into 5 hazard zones and suggested a basic model for seismic analysis for regular buildings limited to 40 m high, suggesting linear elastic behavior of the building, and adopting the equivalent lateral force procedure associated with the fundamental mode of vibration for the determination of the resulting base shear force. The assessment and examination of the ability of DSLS-1977 for predicting an appropriate seismic forces for reinforced concrete building system was made by conducting a comparison study with the international building code IBC-2009. Special attention was made to the effect of soil structure interaction involved in the analysis when using IBC-2009 model on the resulting base shear.

KEYWORDS Earthquakes in Libya, seismic analysis, equivalent lateral force procedure soil structure interaction

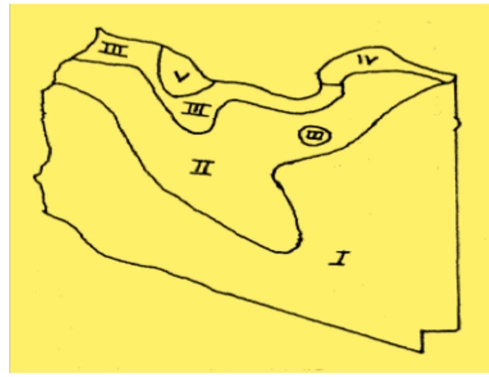
1 Introduction

Following the earthquake of Al-Marj(1963), Dr. Minaml, the UNESCO expert in anti-seismic engineering was invited to study the damage and to submit a report on the relocation and reconstruction of the town.

In that report, Minaml also presented certain recommendations regarding the earthquake resistant regulations for design and construction of buildings and other structures in the Al-Marj region of Cyrenaica and other seismic parts of the country [1]. In 1973, a research programme was started in the civil engineering department of the faculty of engineering university of Tripoli supervised by Professor Mallick to make a seismic study of Libya and to prepare seismic zoning map. Based on the available data on the geology and tectonic structure of the country, fault location, past earthquake history and economic important of the region, Libya has been divided into four earthquake zones, The panel of experts in the Ministry of Housing in 1977 slightly modified Mallick proposed zoning map of Libya to five zones as shown in figure.1 [2].

And producing, a first draft of a code of practice for designing and construction of earthquake resistant buildings entitled **"Criterion and practice for design and construction of earthquake resistant buildings".** denoted here as (DSLS-1977). Most of the contents of the proposed standard have been extracted from the Indian Standard Code of Practice, IS-1893-1975 [3].

Al-Geroushi & Ben Amir (1992) proposed a model for the development a Libyan specification for the calculation of seismic loads on the buildings named as (Garyounis model-1). They made a comparison with the proposed Libyan Specification (DSLS), the forces obtained from the(Garyounis model-1) were found to be larger than the (DSLS) [4].



Zone	I	II	III	IV	V
Seismic coefficient	0.01	0.02	0.04	0.05	0.06

Figure.1: *Seismic zoning map adopted proposed by Ministry of Housing* [2].

By mid -1999, a complete final first draft of IBC was assembled and ready to processed through the new procedures of the International Committee Council ICC, the first edition introduced in 2000. Subsequent IBC code editions were introduced in 2003,2006,2009 and 2012.In the IBC ,the seismic zones of the Unified Building Code UBC1997 were replaced by contour maps giving Maximum Considered Earthquake (MCE) spectral response accelerations at short period (S_s) and 1-second (S_1)for class B soil. The probabilistic MCE spectral response accelerations shall be taken as the spectral response acceleration represented by a 5% damping acceleration response spectrum having a 2% probability of ecceedance within a 50 year period.

It is aimed in this work to use the DSLS-1977 model for seismic analysis of building of reinforced concrete moment resisting frame assembly, illustrate the shortcoming in DSLS-1977 using IBC-2009 as a base code, show suitable conditions in order to use Equivalent Lateral Force Procedure of IBC-2009 applied for the Libyan case, and discuss the effect of soil condition and soil structure interaction (SSI).

2 Static analysis procedures in DSLS -1977 and IBC-2009

The several analytical methods usually adapted for earthquake analysis are mentioned in DSLS-1977, however only detailed steps of, the coefficient method employing equivalent static method ESLF is available. [2],

In the IBC-2009, the American Society of Civil Engineering (ASCE7-2005) remains the primary reference for determining earthquake, snow and wind loads [5], hence the "equivalent lateral force" analysis (ELF) according to ASCE7-2005 may be applied to all structures with S_{Ds} less than 0.33g and S_{D1} less than 0.133g. as well as structures subjected to higher design Spectral response accelerations. If the structures do not meet certain requirement, more sophisticated dynamic analysis procedures must be used otherwise. Table.1 contains the required parameters to be evaluated for the application of the two codes related to the calculated steps for the evaluation of base shear in each case .

Table 1: *Basic requirements of DSLS -1977 and IBC-2009 (Static Analysis)*

Code	DSLS	IBC
Method	ESLF	ELF
Main equation	$V = C\ \alpha_h W$	$V = S_{DS} / (R/I) W$
Seismic Coefficient	α_0 (one value)	S_s & S_1 (contour lines)
Site class	3 Classes (TI,TII&TIII)	5 Classes (S_A, S_B, S_C, S_D & S_E)
Soil coefficient	β_0	F_a & F_v : site coefficient Table 11-4-1& Table 11-4-1
Important factor I	I	I
Time period fundamental period	$T = \frac{0.09\ H}{\sqrt{D}}$ H: height of the structure. D: dimension parallel to the applied seismic force	$T = C_t\ h_n^x$ h:height ,C_t & x: coefficient Table 12-8-2
Ductility	flexibility of the structure $C = \frac{0.50}{T^{1/3}}$	response modification factor (R) Table 12-2-1
Limitations of base shear equation	-	$Cs_{max} = S_{DS} / (R/I)$ for $T \leq TL$ $Cs_{max} = S_{DS} / (R/I)$ for $T > TL$ $Cs_{min} = 0.01$
Building Height	Not exceeding 40 m	$S_{Ds} < 0.33g$ $S_{D1} < 0.133g$
Seismic weight	W: Total dead load + portion from live load to the frame defined as follow: - if (L.L ≤ 3 KN/m²) portion of L.L =25% if (L.L > 3 KN/m²) portion of L.L = 50%.	W: Total dead load + portion from live load to the frame defined as follow: - in areas used for storage, a minimum of 25 % of the floor live load where provisions for partitions is required in the floor load design, the actual partition weight or a minimum weight of 10 psf(0.48 KN/m2) of floor area, whichever is greater

3 Application of DSLS-1977 and IBC-2009.

The assessment of Draft of Suggested Libyan Standard (DSLS-1977) is suggested to be carried out by testing its adequacy to produce comparable results with a well known code such as IBC-2009. Prior to IBC code, the Uniform Building Code (UBC 1997) was used in many countries as a code for calculating seismic forces, and Section 1653 Division III Volume II in UBC 1997 used to determine seismic zone for areas outside USA, values for seismic zone for Libya were illustrated in appendix(C) in UBC 1977 [6].

3.1 Considered spectral response acceleration

The most important factors in the use of IBC code was Ss and S_1. In this work , for the sake of comparison and since there are no mapped values available for Libya in the (IBC-2009). After searching, two methods were found to evaluate S_{Ds} and S_{D1} for the regional map of Libya [7].

Method 1

In this method the design spectral response acceleration S_{Ds} and S_{D1} can be calculated using the following equivalency relationships:-

$S_{Ds} = 2.5\ C_a \quad S_{D1} = C_v$

Where : C_a and C_v = Seismic coefficients

According to appendix of chapter16 in UBC-1997 Libya and Tripoli are classified as 2A, and according to Table 16-I the seismic coefficient Z equal (0.15) from Tables 16-Q and 16-R C_a and C_v can be calculated for each soil type and then calculate S_{Ds} and S_{D1}using the equivalency relationships, the values of S_{Ds} and S_{D1} are presented in Table.2.

***Table 2:** Values of S_{Ds} and S_{D1} calculated by Method 1*

Seismic Zone		Seismic Zone Factor Z	Soil Type	C_a	C_v	$S_{Ds} = 2.5C_a$	$S_{D1} = C_v$
TRIPOLI	2A	0.15	S_A	0.12	0.12	0.300	0.12
Section 1653 Division III Volume II UBC 1997			S_B	0.15	0.15	0.375	0.15
			S_C	0.18	0.25	0.450	0.25
			S_D	0.22	0.32	0.550	0.32
			S_E	0.30	0.50	0.750	O.50

Method 2

In this method the values of maximum considered earthquake S_s and S_1 can be obtained from those references which given values of Ss and S_1 for the location outside USA. Table G-1 in reference [8] gives values of S_s and S_1 for Tripoli illustrated in Table.3.

Table 3: *Earthquake loading data at additional locations outside of the united states*

Continent/Region	Country	Base/ City	Ss(%g)	S_1 (%g)	10/50* S_s(%g)	10/50* S_1(%g)
Africa	Libya	Tripoli	57.1	22.9	28.6	11.4

*10/50 it means ground motions with 10% chance of exceedance in 50 years, and the corresponding mean return period (the average number of years between events of similar severity is 500 year.

these values were used to calculate S_{Ds} and S_{D1} the results are tabulated in Table.4. The comparison between Method 1 and Method 2 are illustrated in Table .5 , it is noticed that the values calculated by method 1 are generally higher and range from 65% to 97% .

Table.4: *Values of S_{Ds} and S_{D1} evaluated by method 2*

10/50 S_s (%g)	0/50 S_1 (%g)	Site class	F_a	F_v	$S_{Ms} = F_vS_s$	$S_{M1} = F_vS_1$	$S_{Ds} = 2/3\ S_{Ms}$	$S_{D1} = 2/3\ S_{M1}$
		S_A	0.8	0.8	0.229	0.091	0.152	0.060
0.286	0.114	S_B	1.0	1.0	0.286	0.114	0.190	0.076
		S_C	1.2	1.69	0.343	0.192	0.228	0.128
		S_D	1.57	2.34	0.449	0.266	0.299	0.177
		S_E	2.38	2.38	0.680	0.394	0.453	0.262

Table 5: *Comparison between Method 1 and Method 2 values.*

	Method 1		Method 2	
Site class	$S_{Ds} = 2.5$ Ca	S_{D1}= Cv	$S_{Ds} = 2/3\ S_{Ms}$	$S_{D1} = 2/3\ S_{M1}$
S_A	0.300	0.12	0.152	0.060
S_B	0.375	0.15	0.190	0.076
S_C	0.450	0.25	0.228	0.128
S_D	0.550	0.32	0.299	0.177
S_E	0.750	0.50	0.453	0.262

3.2 Proposed values

In this work the values evaluated by (Method 2) are adopted. However, based on the values proposed for Tripoli and correlating them with that based on seismic zoning map adopted by Ministry of Housing 1977, using linear interpretation between the zones it became possible to propose an approximate values for the whole zones of Libya as shown in table.6.

The values proposed in this work for Libya was compatible with classification of S_s and S_1 for Region of Seismicity illustrating in reference [9] .Take into consideration Libya classifying as region of low to moderate seismic activity. Housing and Infrastructure Board and its consulting American company referred as (ACEOM) prepare a guidance document and they suggested a zoning map of Libya illustrated in figure 2., and propose a values for S_s and S_1 in each zone [10]. Table .6 showing the comparison of the proposed values in this work and those proposed (ACEOM).

Table.6: *Proposed values of S_s and S_1 and comparison with AECOM values.*

LIBYAN MAP ZONE	Values proposed in this work		Values Proposed by AECOM	
	S_s	S_1	S_s	S_1
1	0.0715	0.0285	0.06	0.02
2	0.143	0.057	0.125	0.04
3	0.286	0.114	0.25	0.08
4	0.3575	0.1425	0.31	0.09
5	0.4290	0.171	0.37	0.11

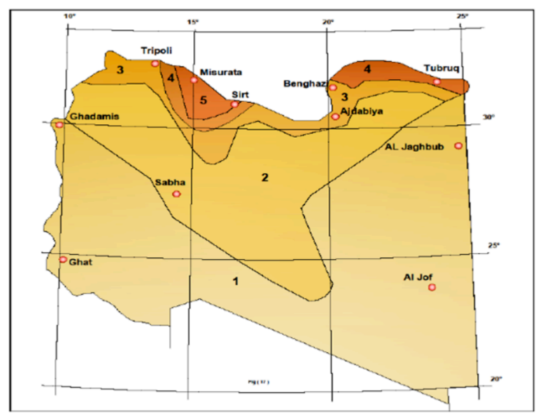


Figure.2. *Libyan map and seismic zones[10].*

4. Case Study

The investigated buildings are located in Tripoli and consist of a multistory reinforced concrete moment resisting frame structure, with an area 7 bays in X-direction 5m center to center and 3 bays in Y-direction 6m center to center. The plan is shown in figure. 3 and elevation heights of 5, 9 and 13 floors are shown in figure.4. The problem analyzed using both Draft of suggested Libyan standard (DSLS-1977) and the International Building Code (IBC-2009) .

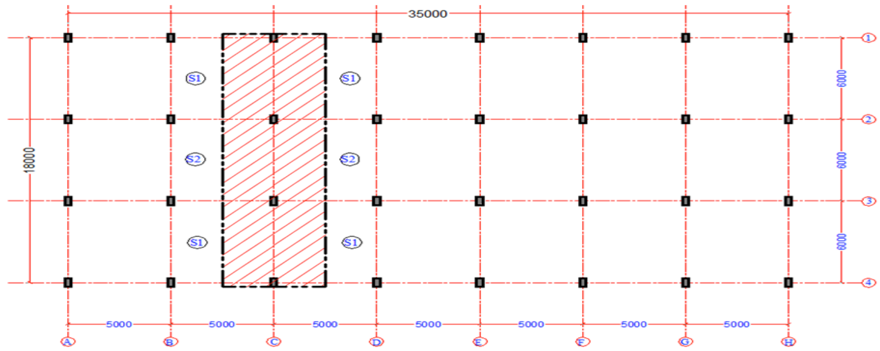


Figure. 3 : *Plan configuration (all dimension in mm)*

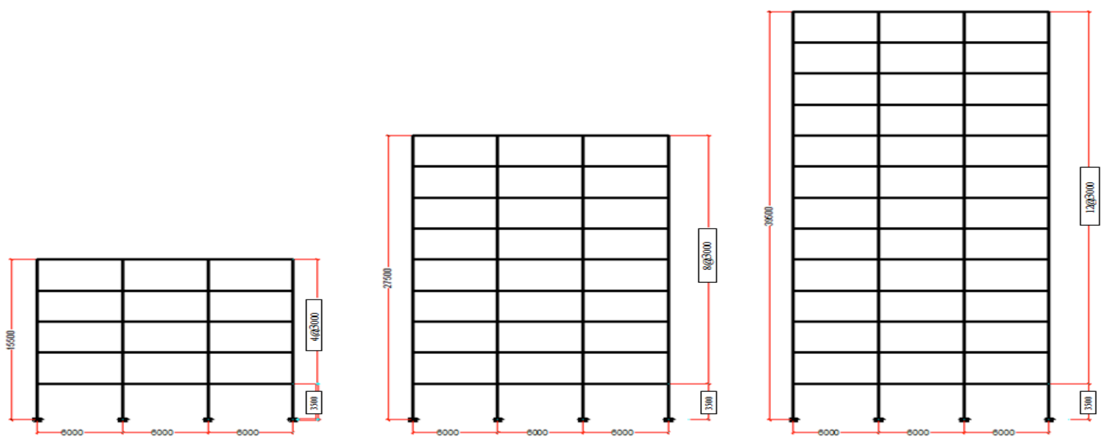


Figure .4: *Elevation configuration (all dimension in mm)*

4.1 Problem description

Element dimensions and planer aspect ratio are selected to satisfy the requirement of both codes for equivalent static analysis, The structures are regular in both vertical and horizontal directions consist of frame system of beams and columns supporting reinforced concrete hollow block slabs of (30 to 35cm) thick and column dimensions (25x60cm) ,(30x70cm) & (40x80cm) for 5,9 and 13 floors respectively ,the frame spacing is 5m and the type of the foundation condition adopted as raft foundation.

4.2 Site class consideration

The three types of soil in the Draft of suggested Libyan standard (DSLS- 1977), are corresponding to five types of soil in the International Building Code (IBC-2009) and presented in Table.7 and fairly matching them to allow reasonable comparison between the two codes.

Table 7: *Soil type in DSLS -1977 and corresponding type in IBC-2009*

DSLS- 1977		IBC -2009	
SOIL TYPE	SOIL DESCRIPTION	SOIL TYPE	SOIL DESCRIPTION
-	-	S_A	Hard rock
TYPE (I)	Rock or Hard Soils.	S_B	Rock
TYPE (I)	Rock or Hard Soils.	S_C	Very dense soil and soft rock
TYPE (II)	Medium Soils.	S_D	Stiff soil profile
TYPE (III)	Soft Soils.	S_E	Soft soil profile

5. Base shear calculations

The ground motion parameters required by the two codes for the calculation of base shear using static procedure were derived according to the governing equations previously explained. The calculations are presented in two spread sheets, Table.8 illustrating the base shear evaluated by Equivalent Static Lateral Force (ESLF) stated in (DSLS-1977), the results indicate that the resulting base shear is directly function of height of the building and no effect by the foundation soil. Table.9 illustrating the base shear evaluated by (ELF) and it can be clearly shown that the resulting base shear magnitude is a function of both building height and also significantly affected by foundation soil**.** A general overview of the results show that the base shear produced by IBC-2009 in all cases of greater magnitude than that predicted by DSLS-1977

Table 8*:* *Base shear calculated by ESLF*

$V_b = C\alpha hW$												
	Step 1	Step2					Step3	Step4	Step5	Step6	Step7	Step8
CASE	α_0	*Soil*	Foundation system	β	N	*h* *m*	*T sec*	C	I	$C\beta I\alpha o$	*W* KN	V KN
5-Storey	0.04	T(I) Rock or Hard soils	Raft	1	5	15.5	0.5	0.6298	1.00	0.0252	34544	870
5-Storey		T(II) Meddium soils	Raft	1			0.5	0.6298	1.00	0.0252	34544	870
5-Storey		T(III) Soft soils	Raft	1			0.5	0.6298	1.00	0.0252	34544	870
9-Storey	0.04	T(I) Rock or Hard soils	Raft	1	9	27.5	0.9	0.5179	1.00	0.0207	62627	1297
9-Storey		T(II) Meddium soils	Raft	1			0.9	0.5179	1.00	0.0207	62627	1297
9-Storey		T(III) Soft soils	Raft	1			0.9	0.5179	1.00	0.0207	62627	1297
13-Storey	0.04	T(I) Rock or Hard soils	Raft	1	13	39.5	1.3	0.4582	1.00	0.0183	90710	1662
13-Storey		T(II) Meddium soils	Raft	1			1.3	0.4582	1.00	0.0183	90710	1662
13-Storey		T(III) Soft soils	Raft	1			1.3	0.4582	1.00	0.0183	90710	1662

Table 9: *Base shear calculated by ELF*

$V = S_{DS}/(R/I)$ **W**																							
	Step1	Step2	Step3		Step4				Step5A		Step5B		Step 6	Step 7	Step 8	Step 9						Step 10	Step 11
CASE	Occ Fac	Imp (I)	S_s	S_1	site class	Soil profil name	*Fa*	*Fv*	$S_{MS}=FaS_S$	$S_{M1}=FvS_1$	$S_{DS}=2/3(SMS)$	$S_{D1}=2/3(SM1)$			R	*h* m	*Ct*	*x*	*Tsec*	$C_S=S_{DS}/(R/I$	$C_{S...}=S_{D1}/T(R/I)$	W KN	*V* KN
5-St	II	1.0	0.2860	0.1140	SA	Hard Rock	0.80	0.80	0.2288	0.0912	0.1525	0.0608	SDCB	SDCB	5	15.5	0.0466	0.90	0.5491	0.0305	0.0221	34544	765
5-St		1.0			SB	Rock	1.00	1.00	0.2860	0.1140	0.1907	0.0760								0.0381	0.0277		956
5-St		1.0			SC	Very dense soil and soft	1.20	1.69	0.3432	0.1927	0.2288	0.1284								0.0458	0.0468		1581
5-St		1.0			SD	Stiff Soil Profile	1.57	2.34	0.4490	0.2668	0.2993	0.1778								0.0599	0.0648		2068
5-St		1.0			SE	Soft Soil	2.38	3.46	0.6807	0.3944	0.4538	0.2630								0.0908	0.0958		3135
9-St		1.0			SA	Hard Rock	0.80	0.80	0.2288	0.0912	0.1525	0.0608			5	27.5			0.9200	0.0305	0.0132	62627	828
9-St		1.0			SB	Rock	1.00	1.00	0.2860	0.1140	0.1907	0.0760								0.0381	0.0165		1035
9-St		1.0			SC	Very dense soil and soft	1.20	1.69	0.3432	0.1927	0.2288	0.1284								0.0458	0.0279		1749
9-St		1.0			SD	Stiff Soil Profile	1.57	2.34	0.4490	0.2668	0.2993	0.1778								0.0599	0.0387		2421
9-St		1.0			SE	Soft Soil Profile	2.38	3.46	0.6807	0.3944	0.4538	0.2630								0.0908	0.0572		3580
13-St		1.0			SA	Hard Rock	0.80	0.80	0.2288	0.0912	0.1525	0.0608			5	39.5			1.2745	0.0305	0.0095	90710	865
13-St		1.0			SB	Rock	1.00	1.00	0.2860	0.1140	0.1907	0.0760								0.0381	0.0119		1082
13-St		1.0			SC	Very dense soil and soft	1.20	1.69	0.3432	0.1927	0.2288	0.1284								0.0458	0.0202		1828
13-St		1.0			SD	Stiff Soil Profile	1.57	2.34	0.4490	0.2668	0.2993	0.1778								0.0599	0.0279		2532
13-St		1.0			SE	Soft Soil Profile	2.38	3.46	0.6807	0.3944	0.4538	0.2630								0.0908	0.0413		3743

5.1 Consideration of soil structure interaction (SSI) by IBC code.

Buildings are subjected to different earthquake loading and behave differently with diversification in the types of soil condition. The process in which the response of the soil influences the motion of the structure and the motion of the structure influences the response of the soil is termed as SSI. In the IBC-2009, and the American Society of Civil Engineering (ASCE7-2005) a methodology for the design of building structure including the effect of soil structure interaction (SSI). The application of this methodology in sequence steps for considering the effect of SSI on base shear values using the equivalent lateral procedure (ELF), are illustrating in Table.10.

Table 10: *Steps for calculating reduction in base shear*

Step	Description	Formula	source
1	Previous parameters	S_{D1}, T, C_s	Table 9
2	Effective building height and weight	$\bar{h}$: the effective height 0.7 h $\bar{W}$:the effective seismic weight= 0.7 W.	Section 19.2 ASCE 7-05
3	Shear wave velocity	(Vs / Vso),	Table 19-2-1 ASCE 7-05
4	average unit weight of the soils and the average shear wave velocity	Calculated or assumed	Table 19-2-1 ASCE 7-05
5	relative weight density of the structure and soil	$\alpha = \bar{W} / (\gamma A_O h)$	Eqs 19-2-6 ASCE 7-05
6	dynamic foundation stiffness modifier for rocking	α_θ	Table 19-2-2. ASCE 7-05
7	the effective period of the structure	$\bar{T}=T\sqrt{1+\frac{25\propto r_a\bar{h}}{v_s^2T^2}(1+\frac{1.12r_a\bar{h}^2}{\propto_\theta r_m^3}}$	Eqs 19-2-5 ASCE 7-05
8	$\bar{Cs}$ using the fundamental natural period of the flexibility supported structure($\bar{T}$)	$\bar{Cs}=\frac{S_{D1}}{\bar{T}\frac{R}{I}}$	Eqs 12.8-3 ASCE 7-05
9	effective damping factor for the structure-foundation system	$\bar{\beta} = \beta_0 \frac{0.05}{(\frac{\bar{T}}{T})^3}$	Eqs 19-2-9 ASCE 7-05
10	reduction in the base shear	$\Delta V = \left[C_s-\bar{C}_s(\frac{0.05}{\bar{\beta}})^{0.4}\right]\bar{W} \le 0.3W$	Eqs 19-2-2 ASCE 7-05
11	Reduced Base shear	$\bar{V} = V - \Delta V$	Eqs 19-2-1 ASCE 7-05

5.2 Overview of the Results and the effect of SSI.

The general overview of the resulting base shear presented in Table.11 indicate that the values of base shear calculated by IBC-2009 is mostly higher than that which is calculated by DSLS-1977. However, when SSI is considered in IBC-2009, the reduced base shear sometimes becoming lower than DSLS-1977 specifically when soil condition is hard. The values of base shear calculated by IBC-2009 increase when the type of the soil generally change from hard to soft, whereas the values of base shear calculated by DSLS-1977 are not affected by the change of ground condition, this related to the dependency only on the height of structure (Number of floors). However, by taking the base shear values produced by DSLS-1977 as a base for comparing the difference in percent between the results of the two codes, the equation will be in the following form: -

$$\frac{IBC_{value}-DSLS_{value}}{DSLS_{value}}$$

The results are presented in Table 11, they indicate wider range of differences between IBC-2009 and DSLS-1977 as soil becoming weaker. The percent differences are getting lesser with increasing building height. For 5-stories case as in Table 11a the percent difference is (9.89) corresponding to soil type T(I)&S_B, and gradually increases to reach (259.2) corresponding to soil type T(III)&S_E. For 9-stories case as in Table 11b the percent difference is (-19.64) corresponding to soil type T(I)&S_B and gradually increases to reach (177.95) corresponding to soil type T(III)&S_E. For 13-stories case as in Table 11c the percent difference is (-34.42) corresponding to soil type T(I)&S_B, and gradually increases to reach (126.85) corresponding to soil type T(III)&S_E. However, by considering the effect of SSI the base shear reduced by considerable amount as shown in Table.11 . For 5-storey case as in Table 11a the percent difference is (-14.88) corresponding to soil type T(I)&S_B and gradually increases to reach (152.24) corresponding to soil type T(III)&S_E. For 9-storey case as in Table 11b the percent difference is (-34.75) corresponding to soil type T(I)&S_B, and gradually increases to reach (94.57) corresponding to soil type T(III)&S_E. For 13-storey case as in Table 11c the percent difference is (-54.1) corresponding to soil type T(I)&S_B, and gradually increases to reach (58.79) corresponding to soil type T(III)&S_E, but still keeping higher values than DSLS-1977, except for hard ground condition.

Table 11a: *Comparison of base shear values (DSLS-1977&IBC-2009) for 5-storey*

	DSLS SOIL TYPE	BASE SHEAR DSLS-1977	IBC SOIL TYPE	BASE SHEAR without SSI IBC-2009 (KN)	BASE SHEAR with SSI IBC-2009(KN)	Percent difference without SSI%	Percent difference with SSI %
			S_A HARD ROCK	765	587		
	T(I) ROCK OR HARD SOIL	870	S_B HARD ROCK	956	741	9.89	-14.88
	T(I) ROCK OR HARD SOIL	870	S_C VERY DENSE SOIL	1581	1132	81.72	30.12
	T(II) MEDIUM SOIL	870	S_D STIFF SOIL PROFIL	2068	1448	137.70	66.39
	T(III) SOFT SOIL	870	S_E SOFT SOIL PROFIL	3125	2195	259.20	152.24

Table 11b: *Comparison of base shear values (DSLS-1977&IBC-2009) for 9- storey*

			S_A HARD ROCK	828	580		
	T(I) ROCK OR HARD SOIL	1288	S_B HARD ROCK	1035	725	-19.64	-43.75
	T(I) ROCK OR HARD SOIL	1288	S_C VERY DENSE SOIL	1749	1224	35.79	-4.95
	T(II) MEDIUM SOIL	1288	S_D STIFF SOIL PROFIL	2421	1695	87.97	31.58
	T(III) SOFT SOIL	1288	S_E SOFT SOIL PROFIL	3580	2506	177.95	94.57

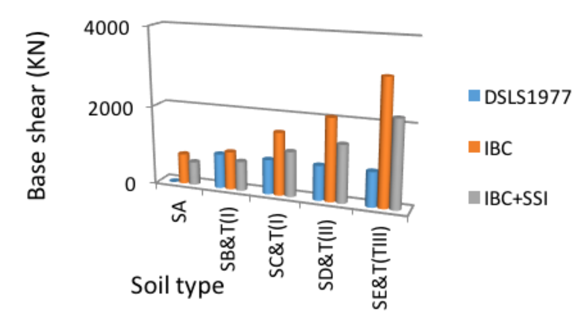
Table 11c: *Comparison of base shear values (DSLS-1977&IBC-2009) for 13- storey*

			S_A HARD ROCK	865	606		
	T(I) ROCK OR HARD SOIL	1650	S_B HARD ROCK	1082	757	-34.42	-54.10
	T(I) ROCK OR HARD SOIL	1650	S_C VERY DENSE SOIL	1828	1280	10.79	-22.45
	T(II) MEDIUM SOIL	1650	S_D STIFF SOIL PROFIL	2532	1772	53.45	7.42
	T(III) SOFT SOIL	1650	S_E SOFT SOIL	3743	2620	126.85	58.79

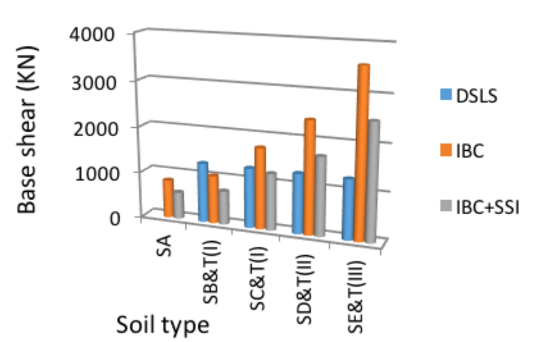
			PROFIL				

The results are also illustrated in graphical form in figure.5 (a,b &,c).

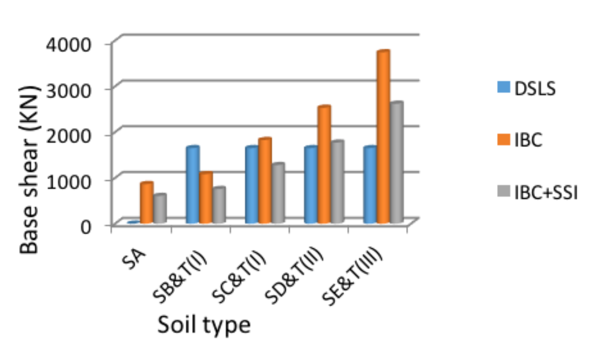
It is clearly shown that the values of base shear calculated by IBC-2009 are generally higher, and is increasing as ground condition getting softer, this is more pronounced in the cases without consideration of SSI.



***a)** Base shear by DSLS&IBC-5 storey*



***b)** Base shear by DSLS&IBC 9-storey*



***c)** Base shear by DSLS&IBC 13- storey*

Figure .5*: Base shear calculation by DSLS-1977&IBC-2009 (5,9 and 13 storey)*

6. General Discussion

The present study does not consider many factors related to structural aspects such as irregularity, ductility, structure system etc., It is essentially focused more on building height, soil condition and SSI, nevertheless, the application procedure experienced in this work for both code requirement allow us to encounter several shortcomings in DSLS-1977 that many modern codes have already overcome, such limitations could be responsible for the differences in the obtained results. The study indicate that for all the investigated cases the resulting base shear, calculated by IBC-2009 is generally higher than the values produced by DSLS-1977. Furthermore, the consideration of soil structure interaction (SSI) by the IBC-2009 has a significant effect on the reduction of base shear even though, it is limited to a maximum base shear reduction due to SSI to only 30% in order to guarantee conservative solution. Current codes and seismic provisions recognize the important rule that the soil structure interaction (SSI) can play on the seismic response of building structures [11], while in DSLS-1977 there is no addressing of SSI and the foundation soil system under the structure is rigid and hence represents a fixed base condition. The type of the soil in IBC-2009 has great influence in base shear values, while in DSLS-1977 the base shear values are not affected by the change of the soil type.

This is due to the soil condition is expressed by DSLS-1977 in terms of the factor β_o which is constant in case of raft foundation and depends only on the type of foundation rather than the type of soil.

7. Conclusion

This study investigates some aspects of the seismic response of reinforced concrete buildings, with emphasize to the effect of soil structure interaction. Special focus is made to local Libyan situation with the aim of evaluating the results obtained from the application of the proposed Libyan specification DSLS-1977, by conducting a comparison with one of the well-known specifications which widely used, specifically the International Building Code IBC-2009. The proposed Libyan specification DSLS-1977 containing many shortcomings and deficiencies, it is not considering many conditions and important factors which are necessary for conducting seismic analysis. It is not including a clear criteria of structural resisting system , structural aspect , structural configuration and soil condition. Furthermore, no consideration by DSLS-1977 for the effect of soil structure interaction SSI which regarded by the present study as very significant and having an important impact in reducing the base shear especially with low strength foundation soil.

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