Analysis of Steel Communication Towers in Iraq Under the Effect of Seismic Loading

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Abstract: The telecommunication industry launched in Iraq two decades ago through three mobile network operators which are holding national licenses; Korek Telecom, Zain Iraq and Asiacell. Since the launch date till now, more than twelve thousand of telecommunication towers have been installed in Iraq holding and transmitting the telecommunication traffic between the Iraqi regions. However, this huge number of towers have been analyzed under the effects of wind loading only without taking into considerations the seismic effects with noting that there are many tremors which have been receded in the recent past. Accordingly, a specific type of towers with different heights have been selected and analyzed under the effects of seismic loading using both equivalent static and response spectrum methods and then the results were compared with the gained results from the wind analysis. After obtaining and analyzing the results, it could be used as a milestone for such a study for the coming telecommunication towers or the existing towers with different topologies and categories.

Keywords: Bracings, Communication Towers, Response Spectrum Analysis, Seismic Analysis, Self-Supporting Towers

1. Introduction

The growing demand for manufacturing and installing telecommunication towers has increased rapidly due to the high increase in the telecommunication business. The increase in the number of the towers leads to increasing the risk of such towers rapidly, therefore sufficient analysis for the environmental loading is highly required in order to avoid any hazardous impact which may result from these towers in case of failure. The telecommunication towers are fabricated from steel and constructed as trussed structures with different bracing patterns. They are constructed as tall steel frame construction to be used in handling the telecom and transmission equipment for telecommunication purposes. The demand for installing such a type of structure; especially in the absence of tall buildings is due to the facts that the steel towers are economical, lightweight and easy to fabricate and erect in comparison with any other types of structures. The telecommunication towers are categorized into three types which are self-supported towers, guyed towers and monopoles. The towers are also divided into two types, roof top towers and ground or green field towers based on their topology. They are also categorized based on the number of legs to four legs and three legs. The self-supported towers are generally preferable due to the smallest area required for implementation purposes, (Pathrikar & Kalurkar, 2017). The focus of this study will be on four legged, green field and self-supporting towers with heights of 40, 60 and 80 m that have been listed in table 1 as this type is the most common type of telecommunication towers in Iraq and the selected heights are due to the fact that these towers are the most common towers that have been used in carrying huge traffic, critical links and connecting many areas to each other thus these towers should be fully functional during the hazards.

Table 1: Properties of the towers

Tower Height		40 m	60 m	80 m
Properties	Tower Type	S.S. Tower	S.S. Tower	S.S. Tower
	Number of Legs	4 – Legs	4 - Legs	4 - Legs
	Tower Topology	Green Field	Green Field	Green Field
	Tower End Shape	Straight End	Straight End	Straight End
Bracings	Straight Portion	X	X	X
	Slant Portion	XBX	XBX	XBX
Heights	Height of slant portion	28m	48m	68m
	Height of straight portion	12m	12m	12m
Bottom Dimensions	Length	4.15m	7.04m	11.73m
	Width	4.15m	7.04m	11.73m
Top Dimensions	Length	1.5m	2m	2m
	Width	1.5m	2m	2m
Number of Sections		22	17	11

The main reason for this study is due to the fact that none of the huge number of telecommunication towers in Iraq has been analyzed under seismic loading or compared the seismic effects with the wind effects while seismic activities in different Iraqi regions could obviously be seen. For that reason, such a study is highly requested to be done to make sure that these towers will not be affected by seismic actions and will not have an effect on people's lives or properties.

The design and drawings of existing towers are used in this study for modeling purpose after checking them on ground to make sure that the mentioned dimensions are correct. The ETABS 17.0.1 software program, (Napier, 2014) has been used for the modeling and analysis purpose for the three selected towers in this study with using ASCE7-16 code, (ASCE7-16, 2017) in the software program. The local seismic parameters are not available in the ASCE code and should be extracted from local codes therefore both Iraqi seismic code versions 2014 (Mijbil, Khalaf, Yousif, Rashied, & Mahmood, 2014) and version 2017 (Mijbil, Khalaf, Yousif, Rashied, & Mahmood, 2017) have been used for this purpose.

2. Literature Review

Amiri, Massah, and Boostan (2007) studied the seismic response of 4-legged self-supported telecommunication towers in Iran under the effects of the design spectrum from the Iranian seismic code. The selected regions to gain the design spectrum values were Manjil, Tabas and Naghan. The researchers selected ten different towers for this study. They found that the wind loads are the dominant load compared with seismic load in general. They also observed that the weight of the accessories has a great effect on the analysis results and should not be neglected. In addition, they observed that the first three flexural modes were enough for analyzing these towers dynamically.

Another study has been done by Konno and Kimura (1973) on the effects of earthquake loads on the lattice telecommunication towers and to obtain the mode shapes, natural frequencies and damping properties of the selected towers and they found that the forces caused by earthquake were greater than the observed forces from the wind loads in some members.

Gunathilaka, Lewanagamage, and Jayasinghe (2013) analyzed four-legged self-supported ground towers with three heights 30 m, 50 m and 80 m in Sri Lanka under earthquake loading preceding the other researchers in this field of study in Sri Lanka. The researchers used the equivalent static method and ANSI/TIA-222-G-2005 code in their analysis. The selected towers have been designed based on wind speeds of 180 km/h and 120 km/h as a recommended wind design speed in this country. The researchers prepared a 3D model design for the analysis of the selected towers by using SAP2000 software program. The values of Ss and S1 have been taken as 0.35 and 0.08 respectively and site soil class has been taken C as the towers are constructed in hard soil. The support reactions, maximum axial forces in leg member and maximum horizontal deflections of each tower with respect to the load combination were obtained from this analysis. The results show that the axial forces on leg members for 30 m tower under severe earthquake loads reached the design values under wind speed of 120 km/h. but overall the study shows that the towers will survive under small and reasonable seismic actions.

3. Methodology

The calculation of wind loading has been done for the comparison purpose with the results of the seismic analysis as well as to make sure that these towers are withstanding the wind loading according to their design. For that, the TIA-222-G code, (Telecommunication-Industry-Association, 2005) along with ASCE7-16 code, (ASCE7-16, 2017) have been used for extracting the required parameters for completing the wind analysis for the three selected towers by ETABS software program while the wind speed has been extracted from the technical specifications of the mobile network operators; Korek Telecom, (Korek-Telecom, 2014) and Zain IQ, (ZAIN-IQ, 2007) as the selected towers have been manufactured based on the specifications of these operators. The solidarity ratio has been calculated manually after loading the towers with their full design capacities. The wind load parameters that have been used for the analysis purpose are mentioned in Table 2. As for the seismic analysis and in order to get more accurate results and due to the variations in seismic parameters from region to region in Iraq, the country has been divided into four regions as mentioned in Figure 1 below. The analysis for each one from the three selected towers for this study has been performed in four selected regions which are shown in Figure 1 with taking into considerations the soil types and selecting the weakest types till reaching the successful models. The requested seismic parameters for completing the analysis purpose thru ETABS program are collected from the two available local code versions which are the Iraqi seismic code version 2014, (Mijbil, Khalaf, Yousif, Rashied, & Mahmood, 2014) and version 2017, (Mijbil, Khalaf, Yousif, Rashied, & Mahmood, 2017) and the analysis has been done twice for each model based on the selected code. The selected seismic parameters along with the selected soil types are collected and tabulated in Table 3.

Table 2: Wind parameters

Parameter		Value
Gust Factor		0.85
Directionality Factor (Kd)		0.85
Exposure Category		C
Topographical Factor (Kzt)		1
Ground Elevation Factor (Ke)		1
Design (Normal) Wind Speed		120Km/h - 126Km/h
Solidarity Ratio	40 m Tower	34%
	60 m Tower	31%
	80 m Tower	30%

Figure 1: Iraq regions map

Table 3: Seismic parameters

Parameter	Iraqi Code – 2014		Iraqi Code - 2017	
Response modification factor "R"	2		2	
Over-strength factor "Ω"	1.5		1.5	
Deflection amplification factor " Cd"	1.5		1.5	
Occupancy category	IV		IV	
Occupancy importance factor " I "	1.5		1.5	
Spectral response acceleration parameter at 0.2 second "Ss"	North (NR)	1.6	North (NR)	0.8
	West (WR)	2.1	West (WR)	1
	Middle-South (MSR)	0.9	Middle-South (MSR)	0.4
	East-South (ESR)	0.3	East-South (ESR)	0.2
Spectral response acceleration parameter at 1 second "S1"	North (NR)	0.5	North (NR)	0.2
	West (WR)	0.8	West (WR)	0.3
	Middle-South (MSR)	0.35	Middle-South (MSR)	0.15
	East-South (ESR)	0.1	East-South (ESR)	0.05
Soil Classification	North (NR)	C, D & E	North (NR)	D & E
	East (ER)	B, C, D & E	East (ER)	C, D & E
	Middle-South (MSR)	D & E	Middle-South (MSR)	E
	West-South (WSR)	E	West-South (WSR)	E

The static analysis represented by the equivalent static method as well as the dynamic analysis represented by the response spectrum method have been selected for the seismic analysis purpose. The load combinations for the analysis purpose have been selected based on the ASCE7-16 constrains to be as mentioned in Table 4.

Table 4: Selected load combinations

Load Case	Case Name	Safety Factors
1	DSTLD 1	Dead X 1 + Antenna X 1
2	DSTLS 1	Dead X 1.4+ Antenna X 1.4
3	DSTLS 2	Dead X 1.2 + Antenna X 1.2 + Wind X 1
4	DSTLS 3	Dead X 1.2 + Antenna X 1.2 + Wind X -1
5	DSTLS 4	Dead X 0.9 + Antenna X 0.9 + Wind X 1
6	DSTLS 5	Dead X 0.9 + Antenna X 0.9 + Wind X -1
7	DSTLS 6	Dead X 1.2 + Antenna X 1.2 + Ex X 1
8	DSTLS 7	Dead X 1.2 + Antenna X 1.2 + Ex X -1
9	DSTLS 8	Dead X 1.2 + Antenna X 1.2 + Ey X 1
10	DSTLS 9	Dead X 1.2 + Antenna X 1.2 + Ey X -1
11	DSTLS 10	Dead X 0.9 + Antenna X 0.9 + Ex X 1
12	DSTLS 11	Dead X 0.9 + Antenna X 0.9 + Ex X -1
13	DSTLS 12	Dead X 0.9 + Antenna X 0.9 + Ey X 1
14	DSTLS 13	Dead X 0.9 + Antenna X 0.9 + Ey X -1
15	DSTLS 14	Dead X 1.2 + Antenna X 1.2 + RS X 1
16	DSTLS 15	Dead X 0.9 + Antenna X 0.9 + RS X 1

4. Results and Discussion

The first coefficient that has been studied in this paper was the resulted base shear from the equivalent and response spectrum seismic analysis for the three selected towers in all the mentioned regions and selected soil types in the methodology and the results for the 40 m, 60 m and 80 m towers have been shown in figures 2, 3 and 4 respectively.

From the figures it could be seen that the resulted base shear values are highest in the case of soil type E considering same region and code version parameter for all the three types of the towers. The results also show that the gained base shear from the seismic parameters of Iraqi code version 2014 are highest than the base shear values that were gained from seismic parameters of Iraqi code version 2017 for all the regions, soil types and in all the three selected towers. The resulted base shear values also show that the east region always gives the highest values in comparing with the rest of the regions follows it the north region while the west-south region is always gives the lowest base shear values.

This means further consideration should be taken in case if the Iraqi code version 2014 will be selected for the design or analysis. In the case if the implemented tower is located in East or North region more consideration should be taken. The soil type should also take into consideration as there is a huge variation in the resulted base shear from type to type for the same region and same code parameters.

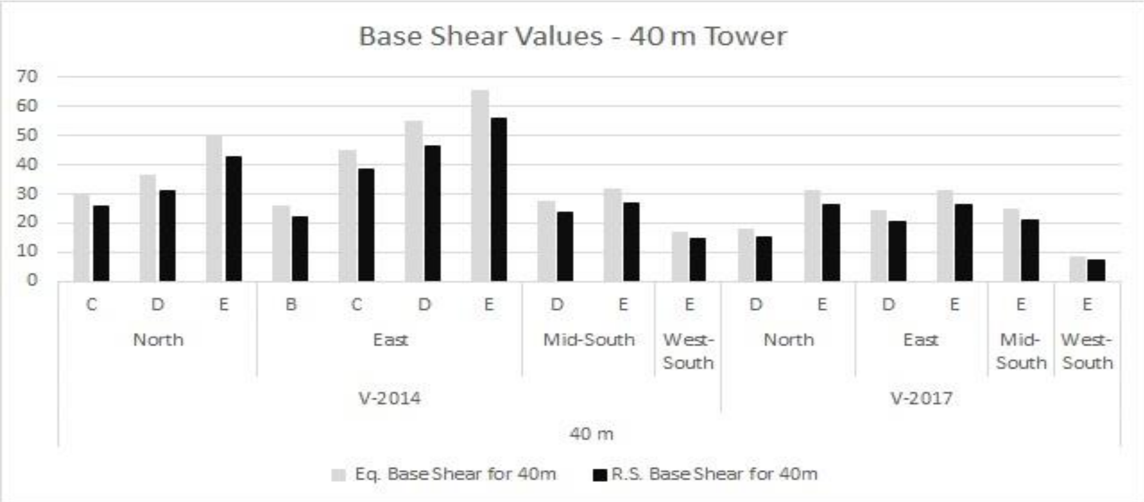

Figure 2: Base shear values – 40 m tower

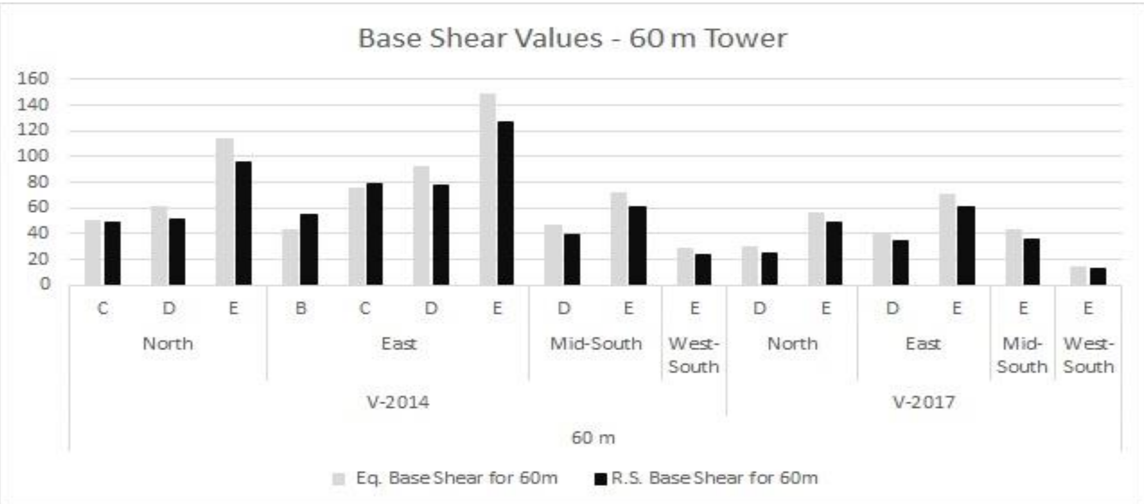

Figure 3: Base shear values – 60 m tower

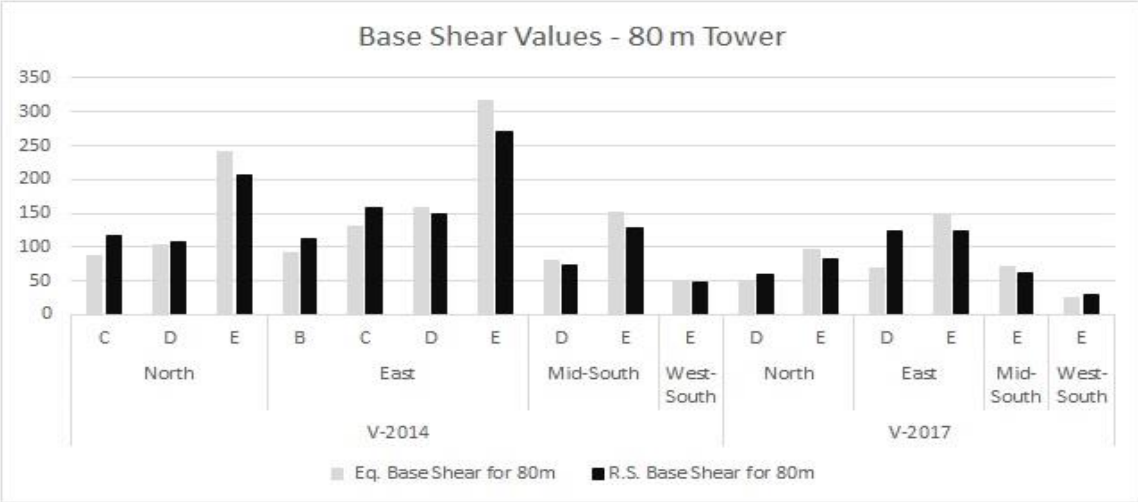

Figure 4: Base shear values – 80 m tower

The second studied coefficient was the maximum drift on the top of the three selected towers for this study in the cases of wind, equivalent and response spectrum seismic analysis with comparing the results with the allowable drift. The results for the 40 m, 60 m and 80 m towers in all the selected regions and site soil types, with both code versions parameters have been shown in Figures 5, 6 and 7 respectively.

The resulted drift on the top of the selected towers shows that the allowable drift value is higher than the obtained drift from all the wind analysis as well as all the selected cases for seismic analysis which means that the selected towers are within the standard in the case of drift. The resulted drift from the seismic loading in both static and dynamic methods exceeds the resulted drift from the wind loading in many cases of study especially in the case of 40 m tower as in this tower the drift gained from seismic loading exceeds the drift from wind loading in thirteen cases out of the sixteen selected cases of study. The resulted drift due to seismic loading for the 60 m tower exceeds the resulted drift from the wind loading in nine cases while in the case of 80 m tower it exceeds the resulted drift from the wind loading in eight cases only out of the sixteen selected cases of study. The resulted drift due to seismic loading are highest in the case of considering the Iraqi code version 2014 in comparison with Iraqi code version 2017 that means more consideration should be taken in case of considering the Iraqi code version 2014 in the design and analysis. The resulted drift due to seismic loading are highest in the east region followed by the north region while the west-south region gives the lowest drift values in all the soil type cases and for all the three selected towers that means more consideration should be taken for the towers in the east and north regions. The soil type E gives the highest drift values followed by the soil type D, thus more consideration should be taken in the case of these two soil types.

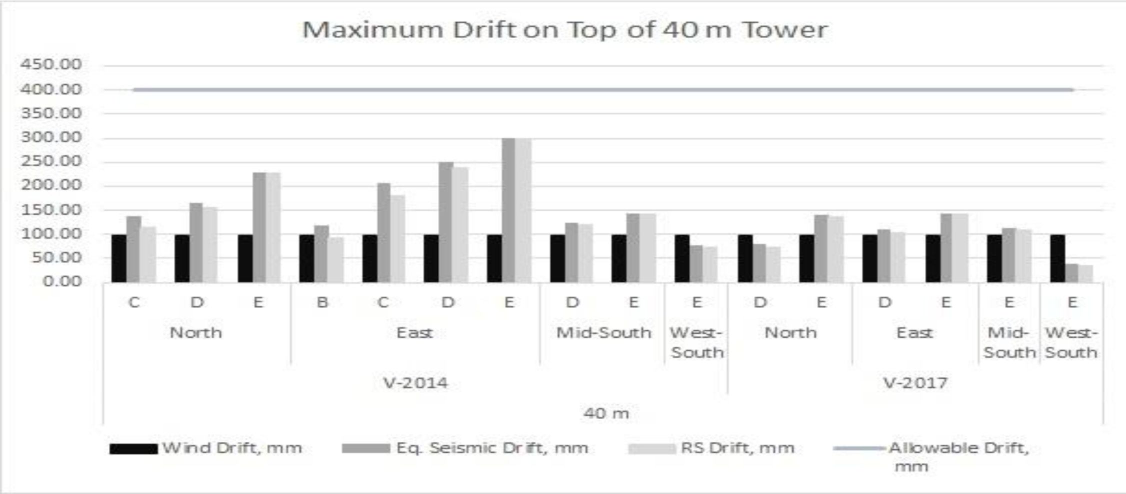

Figure 5: Maximum drift – 40 m tower

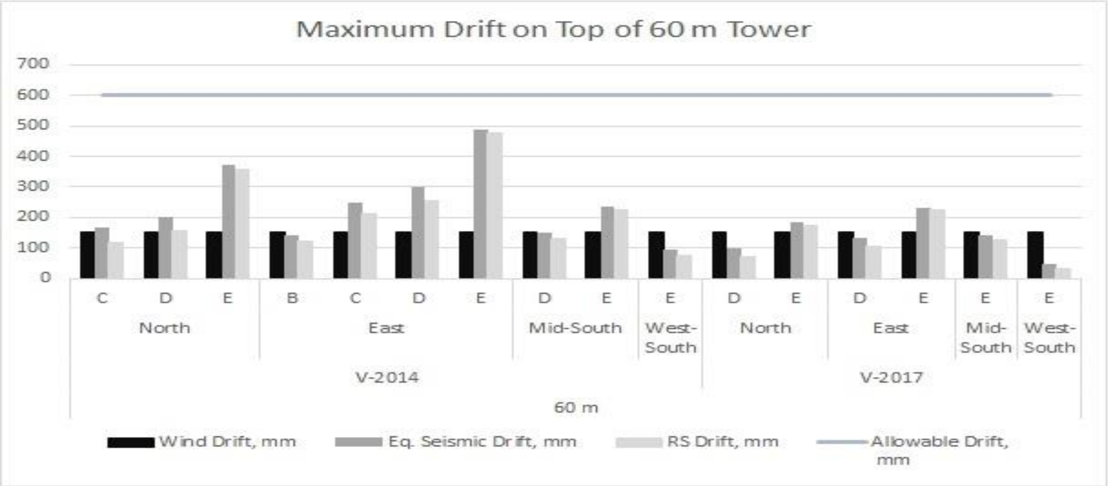

Figure 6: Maximum drift – 60 m tower

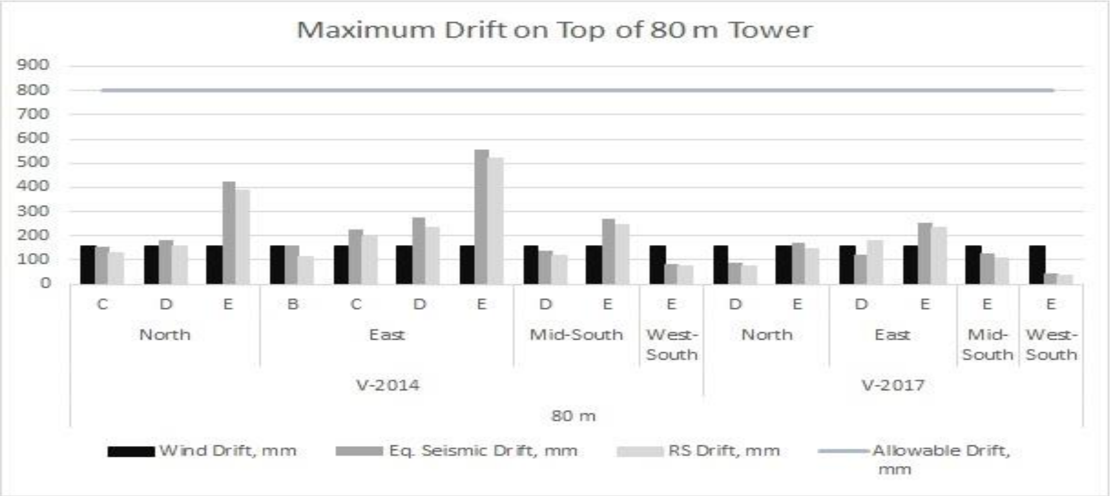

Figure 7: Maximum drift – 80 m tower

The last and the most important coefficient that has been studied is the overall pass and fail checking for the tower members under the effects of wind and seismic loading. The results of the checking under the effects of wind loading based on the selected wind parameters that have been mentioned in the methodology show that all the three selected towers are withstanding the wind loads without a single case of failure.

The pass and fail checking under the seismic loading held based on the selected seismic parameters from both local code versions and site soil classes C, D and E. The results for the three selected towers are tabulated in Table 5.

Table 5: Pass and fail results under the seismic effects

Region	Code Version	Soil Type - C			Soil Type - D			Soil Type - E		
		40 m	60 m	80 m	40 m	60 m	80 m	40 m	60 m	80 m
North	2014	Pass	Pass	Pass	Pass	Pass	24	16	136	96
East		8	48	Pass	32	8	72	48	222	168
Mid - South		Pass	Pass	Pass	Pass	Pass	Pass	Pass	32	8
West - South		Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
North	2017	Pass	Pass	Pass	Pass	Pass	Pass	Pass	16	Pass
East		Pass	Pass	Pass	Pass	Pass	Pass	Pass	32	Pass
Mid - South		Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
West - South		Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass

The results in Table 5 show that there are many fail cases in tower members in the three selected towers especially when selecting the code version 2014 therefore higher consideration should be taken in case of selecting this code in the design or analysis of the telecommunication towers. The soil type has a great effect on the results as the failure in towers members in case of soil type E are much higher than the rest of soil types, while the soil type C acts much better than soil type D in regard to the number of failed members; therefore the soil type should be considered in designing and analyzing process. The region also has a huge effect on the results as the towers in west-south region acts much better than the towers in the rest of the regions, while the towers that located in east acts worst that the rest followed by the north region; therefore the region of installation should be considered in designing and analyzing process.

5. Conclusion and Recommendations

5.1 Conclusion

From the gained results the following points could be concluded:
The three selected towers withstand the wind loading without requesting any modification in their designs. The resulted drift from the seismic loading in many cases especially in the north and east regions are more than the resulted drift from the wind loading. This means that the effects of seismic

should be taken into consideration when designing and analyzing the telecommunication towers. There are many cases of failure in the tower members in all three selected towers under the effects of seismic loading by taking into consideration that the same towers passed under the effects of wind loading. This means that it is a must to take the seismic loading into consideration when designing or analyzing the telecommunication towers in the country of study.

The study expresses four cases of failure in the 40 m and 80 m tower and six cases of failure in the 60 m tower under the effect of seismic loading out of the nine cases that have been considered for the seismic parameters of the Iraqi seismic code version 2014. The failure concentrated in north and east regions with one case of failure only in the middle-south region related to 60 m and 80 m tower in the case of soil type E. This means that if this code has been considered, a huge consideration should be taken in designing the towers especially in the east region first then in the north region. In the case of using the seismic parameters of Iraqi seismic code version 2017, it seems that there are only two cases of failure in the 60 m tower in the north and east regions in the case of soil type E. This means a treatment for 60 m tower need to be done only in the case if the tower installed in soil type E and in east or north region.

5.2 Recommendations

From the study, the following points are recommended:

Working on credence one local code for the seismic effects with logical seismic parameters is recommended for the future work. The telecommunication industry has no limitations therefore there will be new sites to be added to expand the telecommunication network and new towers will be manufactured. For the new manufactured towers, the seismic analysis should be considered. In order to avoid the extra cost for manufacturing the new towers with bigger member sizes due to seismic loading in all of Iraqi regions, the manufacturing could be done based on the region of installation as what happen in this study due to variations in the seismic parameters from region to region. Additional studies to be held on the remaining types of the towers that have been installed in Iraq considering the effects of seismic loading as this paper does not cover all the tower types and topologies in the selected country of study.

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