Severity of Damage Due to 2017 Kurdistan Region of Iraq-Iran border Earthquake (Halabja Earthquake)

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Abstract. On 12th of November 2017, a major earthquake of a magnitude of M 7.3 hit Halabja and caused severe structural damage and collapse in Iran, however, only a few areas of Iraq were mildly affected by it. It was considered the deadliest earthquake of the year as its casualties surpassed 400 people most of which were in Iran. Halabja, was only 32 km away from the epicenter, yet the quake caused no noticeable structural damage to the buildings and no casualties or serious injuries were reported from there. This paper presents the possible engineering reasons behind the gigantic gap of severity of the damage between Kurdistan region of Iraq and Iran. The analysis is done after a series of site visit to Darbandikhan and Halabja and taking more than 300 photographs of the damaged and collapsed buildings. Several crucial factors are discussed in detail, the major of which is directionality effects of the quake as its epicenter was in Iran and the quake caused a meter of slip towards south and half a meter of displacement towards west of the epicenter. Due to the directionality effect, the damage was more in the south and the west of the epicenter knowing that most parts of Kurdistan region of Iraq were located at the north of the epicenter. It is also found that the geological location of the buildings was insignificant in increasing the damage level of the buildings.

Keywords: Earthquake effects; Structural damage levels; Halabja Earthquake; Directionality

1. Introduction
Approximately 10 to 20 strong earthquakes of a magnitude of M 7 and above hit the earth every year,
one of which occurred in Iraq-Iran region on 12th of November 2017 at 18:18 GMT. The magnitude of the earthquake was M 7.3 according to (USGS, 2017). The name was attributed to Halabjah by (USGS, 2017) as its epicenter was only 32 km south of Halabjah, a city in Kurdistan region of Iraq, with the local depth of 23 km, even though the epicenter was in Iran near Ezgelecity in Kermanshah province at 34.905°N latitude 45.956°E longitude. Various agencies specified different exact locations of the epicenters, however, all of them confirmed that it was near Ezgele, therefore, some other names are attributed to it such as Ezgele earthquake(Alavi et al., 2018). The quake had some foreshocks of different magnitudes ranging from M 1.9 to M 4.5 and 529 aftershocks with magnitudes ranging from M 1.8 to M 4.7 until 28th of November 2017 (Alavi et al., 2018).

The mechanism of faulting of the tremor was thrust faulting as a result of movement of Arabian as it is being pushed away by Eurasia Plate. There are two main active faults which are Zagros Mountain Front Fault (MFF) and High Zagros Fault (HZF) which are considered in interpreting the cause of the main quake with a peak recorded ground acceleration of 681 cm/s²-N-S and 585 cm/s²-W-Ein Sarpol-e-Zahab earthquake station(Yekrangnia et al., 2017). More than 1,800,000 people live within 100 kilometers of the epicenter of the quake, 10,000 of which were injured and approximately 500 of them were in Iraq. It was considered as the deadliest earthquake of the year with more than 400 people died, 10 of the dead were reported to be in Iraq and the rest were in Iran(IFRC, 2018). In terms of structural damage, it caused damage to more than 12000 buildings in Iran and some building collapse and some buildings were severely damaged in Kurdistan Region of Iraq (Taha & Hasan, 2018; Yekrangnia et al., 2017). The affected areas in Kurdistan region of Iraq were Darbandikhan, Halabja, Khanaqin, Kalar, Sulaymaniyah and Erbil knowing that most of the destructions were in Darbandikhan city in Sulaymaniyah governorate with a distance of approximately 40 km from the epicenter. Halabjah was approximately 30 km away from the epicenter and the name of the earthquake was attributed to it, yet, no serious damages or causalities reported from there. While, the affected areas in Iran were Sarpol-e-Zahab, Qasr-e Shirin and Eslamabade-e gharb. Sarpol-e Zahab with a population of more than 80000 people was 42.35 km away from the epicenter. However, it was the epicenter of the destruction in Iran where more than 85% of the causalities occurred in there with 387 deaths. Qasr-e-Shirin with population of 24000 experienced 16 deaths (Yekrangnia et al., 2017). It was considered as one of the most catastrophic earthquakes in the area that has had influences on reviewing the designing buildings in that vicinity. Comparing Halabjah and Sarpol-e Zahab, it can be seen that Halabjah is closer to the epicenter than Sarpol-e Zahab yet the level of damage and causality is incomparable as Sarpol-e Zahab lost 387 lives of its inhabitants and none was reported in Halabjah. This triggered a question amongst the engineers and designers as to why this huge gap? To answer this question, some of them speculated wrong theories such as lateral forces were counted for in the design stage of the buildings in Kurdistan of Iraq, knowing that most of the buildings were built in an era where the residents built their own houses without consulting with an engineer or the design codes used in calculating earthquake loads are out of date now. Therefore, the major scientific reasons for effects of earthquakes on different areas of a region is discussed in this section to find possible reasons behind the huge gap between level of damage in Kurdistan region of Iraq and Iran due to the same earthquake.

2. Methodology of the work

A research investigation is carried out to study the reasons behind the gap of level of damage between Kurdistan region of Iraq and Iran. For that reason, a series of site investigations were carried out to all the damaged buildings in Kurdistan region of Iraq particularly to Halabjah and Darbandikhan. Firstly, the authors took a trip to Halabjah right after the earthquake on 14th of November, 2017. A thorough investigation was carried out by asking the officials and the locals for the places where they heard of damages or building collapses. In Halabjah, the total of 8 damaged buildings were investigated. Then two site visits were made to Darbandikhan on 14th of November 2017 and on 1st of December 2017. The total of 16 damaged buildings were investigated with the location of the buildings. The damage analysis is carried out using engineering judgement and visual inspection of the buildings.

A thorough investigation is carried out on the impacted places in Iran. Literature was the source of the research including all the reports on the earthquake and the type of buildings in the area. The investigation included reading and taking satellite data of the area hit with the earthquake to find out all
possible reasons behind the huge difference of level of damage between Kurdistan region of Iraq and Iran. Some of the papers that are used as references were preliminary official reports on the earthquake and then later on updated and the rest were investigation performed by humanitarian agencies and local searchers.

In this paper the effects of Halabjah earthquake is investigated in both Kurdistan regions of Iraq and Iran to comprehend the reasons leading to a huge gap between the structural damage in the buildings.

3. Earthquake Effects

Halabjah earthquake had a huge impact on Iran rather than Iraq for numerous of reasons. As described by Thomas Paulay and M. J. N. Priestley (1992), the earthquakes’ effects on a specified area depend on several crucial factors that can vary from one place to another. The main factor of destruction is the fault rupture that occurs during earthquakes which can extend to be larger than a meter therefore, any structure built on those fault lines experience major damage if their foundation is not unified as a raft or mat foundation. Although, this dislocation of earth surface is considered as the most destructive factor for the structures but because it affects only a specific area therefore, it does not establish a major thread. The other factor which is significant and interests most of the structural designers, is the structural response of the structures during releasing energy and the fault slip which depends on various variables and factors. These factors contribute in enhancing structural response for a particular earthquake which causes more damage and sometimes collapse, which are magnitude, the vertical component of the earthquake, intensity, soil type, directionality effects, geographical effects and the quality of the material used in the constructions. In this section each of those details are discussed in detail.

3.1 Magnitude:
The higher the magnitude of an earthquake, the more energy release would be. Each magnitude higher means, the amount of energy released by that earthquake will be 32 times higher than the previous one. It is estimated that an area of 10000 km$^2$ will be affected and structures in that vicinity may be damaged by an earthquake of a magnitude M 7 to M 8. For Halabja earthquake, the magnitude was estimated to be M 7.3 therefore, the whole Iraq- Iran boarder affected by it but the epicenter was in Iran near Ezgele, in Kermanshah Province therefore, the consequences of the quake was more obvious in the surrounding area of the epicenter and the fault lines. Different magnitudes cause different fault rupture lengths for instance an earthquake of a magnitude of M 5+ may cause of a fault slip in a few kilometers while that length can be extended to 400 km if the magnitude increased to M 8. The epicenter of the quake was located in between two active fault lines of Zagros Mountain Front Fault (MFF) of a length of 1368 km and High Zagros Fault (HZF) which its fault length is 1375 km, where the movement of MFF caused the earthquake(Roudbari et al., 2020). Both of these faults are located in Iran. HZF extends from north-west of the epicenter towards south-east in a linear pattern. Whereas the fault line of MFF passes along north-west of the epicenter extending towards west of it on Iraq- Iran border sweeping to the south of the epicenter. Most of the damaged areas were a long those areas where the MFF is passing.

The duration of the earthquake can increase the length of the fault line which can increase the damage as the shock waves arrives later. The duration of Halabja earthquake was 30 seconds which was felt in Caucasus, Turkey and Syria(Yekrangnia et al., 2017).

To show the relationship between the damage caused by an increase in the magnitude of the earthquake, (Nievas et al., 2020) collected a database of 1062 earthquakes with different magnitudes of 4. To 5.5 and plotted on a graph, shown in Figure 1, to show the relationship between the magnitude and the amount number of building destroyed. As it is shown in Figure 1, the earthquakes that caused a destruction of the lower and/ or upper bound of 1000 buildings are the ones which their magnitudes are greater than 4.5.
3.2 Vertical acceleration:

The vertical component of the earthquake is usually neglected by the structural designers and it is usually taken as the two-thirds of the peak horizontal acceleration, however, it is proven that sometimes that the value of the vertical acceleration is as high as the horizontal acceleration especially close to the epicenter. The ground acceleration of the Halabjah earthquake was recorded by 101 stations inside Iran and the strongest peak accelerations were recorded by Sarpol-e Zahab station. Figure 2 shows the vertical acceleration of the quake was 358 cm/s² which considered to be high as the peak was 585 cm/s² in W-E and highest was along N-S with 681 cm/s² (Yekrangnia et al., 2017). This might be adding reasons for the destructiveness of the earthquake.

Figure 2. Peak ground accelerations of Halabjah earthquake (Yekrangnia et al., 2017).
To emphasize the effects of the vertical acceleration on the structures in general. A study on its effects on spacious underground R.C structures is performed by (He & Chen, 2019). They took two other variables into account which are the performance level of the structure varying from fully operational (FO), operational (OP), life safety (LS), and near collapse (NC) and the type of the soil it is built on which varies from stiff site (site I), medium stiff site (site II), medium soft site (site III), and soft site (site IV). They found out that the effects of the vertical acceleration would be significant on the underground structures especially if the type of soil was soft clay regardless of the performance level as it is shown in Figure 3 which represents the results of (FO) on the left and (OP) performance level on the right.

![Figure 3. Peak ground vertical accelerations with the possibility of damage (He & Chen, 2019)](image)

3.3 Intensity:

It is the factor which measures the level of damage and danger on the hit areas which means the effects of the earthquake on a specific region and how the inhabitants felt it. Therefore, it is a subjective assessment based on the level of damage felt by the inhabitants so it has no direct relationship with the magnitude of the earthquake. For instance, (Paulay & Priestley, 1992) stated that both 1986 M 5.4 in San Salvador and the 1985 M 7.8 Chilean earthquake were having the same Peak Horizontal Ground Acceleration of 0.7g. Other factors may contribute in increasing the intensity of quake such as intensity of the population, distance from epicenter and focal depth. The depth of the focus affects the intensity of the quake as the shallower it is, the more intense it would be. The depth of the quake was only 23 km in case of Halabjah earthquake so it has increased the intensity of the quake. Density of population around the area is another factor. According to the United Nations Institute for Training and Research (UNITAR- UNOSAT), who took the survey of a population of 79,000,000 in Iran. From that number, only 1,222,000 people reported to have felt moderate shaking, 178,000 people reported to have felt strong shaking, and 6,800 people reported to have felt very strong shaking. While in Iraq they surveyed the population of 36,000,000 form which only 2,669,000 people reported a moderate shaking effects, 582,000 people testified a strong shaking and 110000 people verified a very strong shaking effect. This variation is due to the density of the population in the affected area which does not indicate the level of damage of the buildings because even though more people in Iraq reported very strong shaking, the number of damaged and collapsed buildings were more in Iran which is an indication that intensity cannot be taken as effective factor but the factors affecting it, can be taken.

3.4 Influence of the soil type:

It is another factor contributing to the amount of structural Damage. As it can be seen in Figure 4, the softer the soil is, the stronger the ground acceleration reading will be because of wave reflection and
amplifying in soft soil.

According to (Roudbari et al., 2020) in the Halabjah earthquake most of the damage occurred in the areas where built on soft soil. For example, two complex residential buildings in Makan-e Mehr in Sarpol-e-Zahab compared namely Karmandi complex which was built on a mountainous area on a foothill with stiff soil or soft rock at 34°28′22″N, 45°50′59″E and ShahidShiroodi complex which was built on a soft soil which was originally farmland and it had a high ground water table at 34°28′1″N, 45°50′39″E (Roudbari et al., 2020). The distance between the two sites is only 1500 m and both sites are approximately 6 to 8 km away from MFF and nearly 45 km away from HZF. After analyzing the damaged buildings, it was concluded that only 4 buildings were damaged on Karmandi complex site while that number was 30 in ShahidShiroodi site. Figure 5 shows the damage consequence that can be observed from a damaged map drawn by (UNOSAT, 2017).

![Figure 4. Soil type effects on amplifying the waves (Charleson, 2012).](image)

![Figure 5. The difference of level of damage due to soil effects in Sarpol-e Zahab (UNOSAT, 2017).](image)
In Kurdistan Region of Iraq, however, generally, a layer of brown clay with lumps of carbonate covers most of the cities. According to the geotechnical conducted by Consulting Engineering Bureau of College of Engineering at Sulaimani University (Rashid, 2008 and Rashid 2012), the mean values of the Unconfined Compression Strength (UCS) for Darbandikhan and Halabja cities were 355.568 kPa and 613.62 kPa, respectively. The UCS of Darbandikhan varies from 158.59 kPa to 885.57 kPa while the UCS of Halabja varies from 167.87 kPa to 1024.88 kPa. Table 1 presents the approximate consistencies of clays on the basis of their unconfined compression strength (Das, 2007). According to Table 1, the consistence of brown clay with lumps of carbonates of the mentioned regions varies from stiff to hard clay. As explained in Figure 4, the stiffer the soil is, the less the amplification of the waves would be leading to less damage as a consequence.

**Table 1.** General relationship of consistency and unconfined compression strength of clays (Das, 2007)

| Consistency   | Unconfined Compression Strength (q_u) |
|--------------|---------------------------------------|
|              | Kg/cm² | kN/m² |
| Very Soft    | <0.25  | <25   |
| Soft         | 0.25-0.50 | 25-50 |
| Medium       | 0.5-1.0 | 50-100 |
| Stiff        | 1.0-2.0 | 100-200 |
| Very Stiff   | 2.0-4.0 | 200-400 |
| Hard         | >4.0   | >400   |

3.5 Directionality effects:

Contrary to the popular believe, it is proven that during a fault eruption, most of the energy propagates in one direction most of the times and not in all directions of the epicenter. Rather, it will release its energy in most of the cases unidirectionally. Further, as it can be seen in the Figure 6, the peak ground acceleration at a downstream, station A, is enhanced by the Doppler effects which caused by the interaction of the shock wave with the waves released from the fault rupture along the fault line. This results in high-amplitude and shorter period of earthquake. However, at the upstream, station B, the amplitude of the ground shaking is low with extended period of time.

**Figure 6.** Directionality effects recreated(Paulay & Priestley, 1992)
According to (Roudbari et al., 2020) directionality effects had inputs in amplifying the localized or directional ground motions in Halabjah earthquake as it did and caused the high level of damage in 1994 Northridge earthquake in California and 1995 Kobe earthquake in Japan due to the wave propagation within the site and direction of the fault rupture both of which affected the near fault rupture directivity effects. The damage due to directionality effects would be higher if the weaker axis of the building is aligned with the stronger horizontal motion of the quake.

To understand the propagation of the waves in Halabjah earthquake, a deeper understanding is needed in the way the ground motion has propagated and the direction of the waves released from the focus. For which, some of the researchers have taken the data from different satellites to understand the amount of the ground displacement in each direction. For example, (Zare et al., 2017) took the data from Sentinel-1 satellite in two different dates namely 30/10/2017 which is before the earthquake and 17/11/2017 which is after it. They used a SNAP software to simulate the motion and as it can be seen from Figure 7, there is an intense propagation of the waves on Arabia plate where most of the structural damage occurred. They used color code to understand the phases each of which represents $2\pi$. They discovered that the Arabia plate has moved nearly a meter while Eurasia plate had moved only 10 cm.

![Figure 7. Ground displacement of the Halabjah earthquake based on Synthetic Aperture Radar (SAR) data (Zare et al., 2017)](image)

Moreover, some other researchers of Geospatial Information Authority of Japan (GIAJ, 2017) observed the crustal deformation by using ALOS-2/PALSAR-2 data. They have observed the substantial displacement of nearly half a meter westward, as it can be seen in Figure 8 and more than 90 cm upwards, as it can be seen in Figure 9, in approximately 20 km NNW of Sarpol-e Zahab. It can be seen from Figure 10 that the propagation of the ground motion waves was from 25 km depth of the focus towards southwest where most of the structural damages occurred. In Halabjah and Kurdistan Region of Iraq, on the other side, the displacement was nearly zero as they were located at the north of the epicenter as it can be seen from Figure 8 and 9. Therefore, the level of damage was not as severe as it was in Iran.
Figure 8. East-West Displacement of Serpol el Zahab (GIAJ, 2017)

Figure 9. Up-Down Displacement of Serpol el Zahab (GIAJ, 2017)
3.6 Secondary effects:
It is believed that the movement of MMF in Sarpol-e Zahab region triggered the earthquake. The quake was strong enough to cause huge landslides, rockslide and liquefaction that caused damage in the direction of the ground motion. For example, in MelaKabod a huge land slide occurred, as shown in Figures 11 and 12, in an area of 4 km² where the maximum horizontal displacement was 34 m and maximum vertical displacement was 10 m (Vajedian et al., 2018). This landslide caused damage to some buildings as reported by (Masakatsu & Setiawan, 2018) observed during their site visit to the location.

Figure 10. Construction of the faults (Model) (GIAJ, 2017)

Figure 11: Land sliding in MelaKabod (Vajedian et al., 2018)

Figure 12: The scale of the landslide (Vajedian et al., 2018)

However, no land sliding has been reported in Kurdistan region of Iraq due to the quake. Additionally, rock sliding was reported in both area of Kurdistan region of Iraq and Iran without mentioning any damage to it, which is reasonable due to vibration at the instance of the earthquake and lack of friction between the rocks. Based on a comprehensive paper on the Darbandikhan dam written by (Yousif et al.,
2019), no damage was attributed to rock falling even though the size of the rocks vary between a few centimeters to 2.5m. Liquefaction is reported to have caused damage and collapse of some buildings in Sarpol-e Zahab due to construction in an area with high level of ground water table in that area and the soil type was originally a farmland (Masakatsu & Setiawan, 2018; Roudbari et al., 2020).

Figure 13 shows the distribution of the collapsed buildings in Darbandikhan which suggests that most of the damage took place in the south and east of the city which is in line with the attenuation of the earthquake wave as they propagated in the direction of south-west. The type of fault slips is thrust faulting. The slip of the fault was only 50 cm towards west which can be considered as the main factor in collapsing the buildings in Darbandikhan while the slip to south was nearly a meter which caused catastrophic damages in Sarpol-e Zahab as it is located to the south of the epicenter.

![Collapsed buildings locations in Darbandikhan from satellite view](https://www.bing.com/maps)

**Figure 13.** Collapsed buildings locations in Darbandikhan from satellite view

3.7 Geographical Effects:

It is true that the response acceleration of structures would be higher with increase of height. Similar effect might be true when it comes to topography of the sites as it is shown in Figure 14 where (Paulay & Priestley, 1992) observed different level of damage for the same location with the same earthquake but different heights. This effect is local, affecting a specific site, therefore, comparison between two cities and ignoring the above factors would not be reasonable.

![Geographical effects](https://www.bing.com/maps)

**Figure 14: Geographical effects(Paulay & Priestley, 1992)**
The altitude of the epicenter was not trivial to find as the epicenter had different locations based on the agencies who calculated them. It was estimated to vary from 763m to 833.5 m. Otherwise, both Darbandikhan and Sarpol-e Zahab have nearly the same altitude of 535m and yet the damages are incomparable.

3.8 Quality of material:
It is another effective factor that causes server injuries and sometimes causalities. Figure 15 shows the relationship between the percentage of damage with quality of material being used in construction (Stein & Wysession, 2009). As it can be seen from the Figure 15, the level of damage of earthquakes of ground acceleration of 0.65 g is nearly a 100% when adobe and brick are used in construction. The ground acceleration of the Halabjah earthquake was nearly 0.7 g and most of the damaged structures in Iran had brick as the main material of the construction.

Figure 15: Effects of quality of materials and level of damage (Stein & Wysession, 2009)

The styles of housing and constructing them are different from Kurdistan region of Iraq and Iran. Based on reports by (Derakhshan, 2017) published in World Housing Encyclopedia (WHE), a large part of the buildings (47.5%) which is nearly a half of the buildings in that area were built with a combination between brick and steel section as it can be seen in Figure 16. Of this portion, 67% was in Sarpol-e Zahab which is considered to be the maximum percentage of this type of the building in the area. As discussed previously, the highest fatality rate was also in Sar-Pol-e-Zahab with 387 deaths.

Figure 4. Percentage of Brick and Steel buildings near the epicenter (Derakhshan, 2017)
Figure 5. Percentage of brick and wood buildings near epicenter (Derakhshan, 2017)

(Alavi et al., 2018) discussed the reasons of this type of building’s failure and mentioned several factors which are improper design of the steel sections, buckling of the compression members, as it can be seen in Figure 18 and improper design and construction in general as it can be seen in Figure 19.
The other common types of buildings in the area were steel frame buildings shown in Figure 20 with the average of 17%, brick and wood building, shown in Figure 17, with the average of 13.8%, concrete buildings shown in Figure 21 with the average of 8%, and adobe and wood buildings with the average of 7%.

However, in Kurdistan region of Iraq, most of the residential houses are masonry buildings built as load bearing walls and constructed with concrete block walls with a concrete slab on top. Also, most of the masonry building consist of one floor or two, therefore, they are not tall structures(Yaseen & Ahmed, 2018). A typical masonry building in Kurdistan region of Iraq is shown in Figure 22. In an analysis, (Yaseen & Ahmed, 2018) took an example like the one shown in Figure 22, and analytically tested it for 59 different ground motions. They deduced that this type of building is only susceptible to light and moderate level of damage and no server damage was observed in their investigation even though they interpreted it as a “questionable” phenomenon. This type of building is strong enough to survive the moderate quakes as it mainly consists of concrete which is stronger than brick and adobe. Similar conclusion can be drawn as the fatality rate was very low in the regions of Iran where the concrete buildings rate was high and the steel buildings rate were medium as it can be seen in figure 20 and 21. While the damage rate was very high in the regions where brick and wood and brick with steel were used in construction as in Figures 16 and 17.
4. Collapse of the buildings in both regions

There were different levels of damage in both Kurdistan regions of Iraq and Iran but when it comes to collapse, some buildings collapsed in Darbandikhan in Kurdistan region of Iraq as did in Iran. The reason of the collapse of these buildings related to structural design, construction and detailing and it is out of the scope of this paper. A collapsed building in Darbandikhan is shown as a satellite image in Figure 23 as in its actual state and the collapsed state. It was an R.C frame of which was three stories high and after the collapse most of the members were did not lose their shapes. However, satellite images from an area in Sarpol-e Zahab is shown in Figure 24 and it looks like an explosion aftermath as brittle materials used in their construction.

Figure 22: Masonry building example in Kurdistan region of Iraq (Yaseen & Ahmed, 2018)

Figure 23: Collapsed R.C frame building in Darbandikhan (35.105141, 45.687696) (a) undamaged building (http://bing.com/maps) (2014) (b) collapsed building (2017)

Figure 24: Collapse of some masonry buildings in Kermanshah, Iran (UNOSAT, 2017)
5. Remarks

Finally, it is worth mentioning that in this paper the major reasons behind the difference of the levels of damage and levels of causality discussed between Kurdistan region of Iraq and Iran based on scientific reasons proved by scientists and expertise in the area of seismology and structural engineering. Only the major reasons were discussed and some of the reasons related structural detailing and analyzing, the design code used in designing the structures and details of their foundations are not discussed in this paper.

Although, the level of damage in Kurdistan region was not as high as it was in Iran, still, the hazards and risks related to earthquakes have to be acknowledged to be prepared for future quakes. Because of this reason, (Issa, 2017) urged the engineers to collaborate on establishing and designing a national code to rely on as a step of preparedness in minimizing the risks attributed to future earthquake loads. Therefore, more thorough investigations needed which cannot be done individually as it takes time, effort and money so there should be a national plan in achieving that goal.

The detail of structural design and the philosophy of design are not discussed in this paper even though they have influences on the destination of a building during an earthquake. However, the paper tried to discuss the main reasons behind that gap between the damage levels in general and the details of the construction and design have not been discussed. Otherwise there might be other factors including the soil, altitude, location, etc. that might have had inputs in the damages. Therefore, there is a strong need for a thorough investigation emphasizing the mistakes in the design and construction of the buildings that led to their collapse. Based on that, a unified national code can be established for all the designers and site engineers which will represent the reality of the buildings as it would have been established based on data collection and site investigations.

6. Conclusion

The level of damage due to an earthquake varies between a place to another. During Halabjah earthquake, the structural damage and causality rates had a huge gap between Kurdistan region of Iraq and Iran, so this paper investigated the reasons in an attempt to interpret that gap. The reasons can be summarized as:

1- Magnitude, intensity, and vertical component of the ground acceleration of the earthquake had their footprints in echoing the damage level in the buildings in Iran. Because the focus and epicenter of the quake was in Iran, so the impact would be logically higher in the vicinity of the epicenter. The vertical component of the acceleration was as high as the horizontal component which might have added reasons of building damages around the epicenter as it will, generally, be ignored in the design.

2- Stiffness of soil plays a crucial role in the buildings that collapsed as most of which were on farmland soils with high level of ground water tables. The soil stiffness in Kurdistan Region, however, can be regarded as stiff which will not amplify the earthquake waves as the soft soils do.

3- Directionality effects can be considered as the main and most effective reason in creating the huge gap in the level of damage between the two areas of the study as the waves traveled south-west of the epicenter while Kurdistan region of Iraq is located at north of the epicenter. The quake had a lateral displacement of 50 cm towards west and 90 cm to a meter of displacement towards south, the two places with most of the damage. The fault movement of MFF which caused the earthquake is located in Iran and most of the damaged area are located in the direction of the wave attenuation.

4- Secondary effects such as land sliding, liquefaction and rock sliding occurred in Iran adding more reasons to increase the damage.

5- Building material quality can be considered another factor in increasing the impacts of the earthquake in Iran as most of the buildings in that area constructed using adobe and brick which are considered as weakest material in resisting lateral loads. Nearly 48% of all the building in the affected area in Iran are made out of brick with steel which is vulnerable to earthquake loads. However, wall bearing system and hybrid or combination between R.C frame and masonry system are mainly used in Kurdistan region of Iraq which can resist earthquake to a satisfying degree if they
build without tolerating principles of earthquake design.

6- The effects of intensity of the quake and geographical location of the buildings were not significant as the former is a subjective decision that changes with intensity of the population and the latter has local effects only.

References

[1] Alavi, E., Mahootchian, A., Yadegari, S., Shamsodin, M., Nouri, M. B., & Ordoubadi, B. (2018). Report of: M7.3 Ezgele, Kermanshah, Iran Earthquake on November 12, 2017. Earthquake Engineering Research Institute, February, 1–22. https://www.eeri.org/wp-content/uploads/Kermanshah-Earthquake-Report-E.A

[2] Charleson, A. (2012). Seismic design for architects: Outwitting the quake. In Seismic Design for Architects: Outwitting the Quake (Vol. 97800808888). https://doi.org/10.4324/97800808888255

[3] Das, Braja M. (2007), Principles of Foundation Engineering 6th Edition. Thomson, 2007.

[4] Derakhshian, S. (2017). Distribution of building types in the earthquake affected regions of Iran. EERI, 2881.

[5] GIAJ. (2017). Crustal Deformation Observed by Synthetic Aperture Radar (SAR). Global Engineers & Technologists Review. http://www.gsi.go.jp/cais/topic171115-index-e.html

[6] IFRC. (2018). Emergency Plan of Action (EPoA) Iraq: Earthquake A. Situation analysis. International Federation of Red Cross and Red Crescent Societies, December 2017, 1–11.

[7] Issa, H. (2017). Earthquakes and building regulations in Kurdistan: a turning point. Kurdistan 24. https://www.kurdistan24.net/en/news/8d8dfd15-cacc-4ff3-b521-8439b19c49fd

[8] Masakatsu, P. M., & Setiawan, H. (2018). Geotechnical Damage on the 2017 Iran- Iraq Earthquake.

[9] Paulay, T., & Priestley, M. J. (1992). Seismic design of reinforced concrete and masonry building (T. Paulay & M. J. Priestley (eds.); first). Wiley interscience publication.

[10] Rashid, Kamal Ahmed (2008), Geotechnical report for Halabja Chemical Diseases Hospital in Halabja city-Halabja Governorate, unpublished report, Consulting Engineering Bureau-College of Engineering-University of Sulaimani.

[11] Rashid, Kamal Ahmed (2012), Geotechnical report for Kindergarten Building in Darbandikhan city/Sulaimani Governorate, unpublished report, Consulting Engineering Bureau-College of Engineering-University of Sulaimani.

[12] Roudbari, S., Heris, M., Hakhamaneshi, M., & Dashti, S. (2020). Mediating Design Claims: The Social Media and Housing Disaster of the 2017 Halabja Earthquake. Natural Hazards Review, 21(2), 1–10. https://doi.org/10.1061/(ASCE)NH.1527-6996.0000352

[13] Stein, S., & Wysession, M. (2009). An Introduction to Seismology, Earthquakes, and Earth Structure (Google eBook). http://books.google.com/books?hl=en&lr=&id=-z80yrWFsqoC&pgis=1

[14] Taha, B. O., & Hasan, S. A. (2018). A Comparative Study of the Seismic Provisions between Iraqi Seismic Codes 2014 and 1997 for Kurdistan Region/Iraq. Eurasian Journal of Science and Engineering, 4(1), 180–192. https://doi.org/10.23918/eajse.v4i1sp180

[15] UNOSAT. (2017). Damaged structures and related density map in Sarpol-e-Zahab, Kermanshah, Iran.

[16] USGS. (2017). Magnitude 7.3 Earthquake Iran/Iraq Border. Website. https://www.usgs.gov/news/magnitude-73-earthquake-iraniraq-border

[17] Vajedian, S., Motaghi, M., Mousavi, Z., Motaghi, K., Fielding, E. J., Akbari, B., Wetzel, H. U., & Darabi, A. (2018). Coseismic deformation field of the Mw 7.3 12 November 2017 Sarpol-e Zahab (Iran) earthquake: A decoupling horizon in the Northern Zagros Mountains inferred from InSAR observations. Remote Sensing, 10(10). https://doi.org/10.3390/rs10101589

[18] Yaseen, A. A., & Ahmed, M. S. (2018). Seismic Vulnerability Assessment of Single-Story Masonry Buildings in Kurdistan Region - Iraq. Academic Journal of Nawroz University, 7(4), 18.
[19] Yekrangnia, M., Eghbali, M., Seyri, H., Panahi, M., Zanganeh, S. Y., Beyti, M., Hayatgheybi, D. S. V., Nazarpour, M., & Amiri, G. G. (2017). *A preliminary report on school buildings performance during M 7.3 Ezgeleh, Iran earthquake of Participants Project Team Steering Committee Advisory Committee. November*. https://www.eeri.org/wp-content/uploads/Report-Kermanshah-DRES-Ver2-2.pdf

[20] Yousif, O. S. Q., Zaidn, K., Alshkane, Y., Khani, A., & Hama, S. (2019). *Performance of Darbandikhan Dam during a major earthquake on November 12, 2017. May*.

[21] Zare, M., Kamranzad, F., Parcharidis, I., & Tsironi, V. (2017). Preliminary report of Mw 7. 3 Sarpole Zahab, Iran earthquake on November 12, 2017. *EMSC Report, 2017(Fig 4)*, 1–10.