Appropriate and Correct Reactions during Earthquakes: "Drop, Cover and Hold on" or "Triangle of Life"

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ABSTRACT

Since many years, the "Drop, Cover and Hold on" (DCH) has been suggested and taught as an acceptable advice internationally for taking proper and correct reactions during earthquakes. "DCH" is designed with the aim of avoiding careless and dangerous behaviors in order to bring less damage to people due to earthquakes. In the last decade, another advice has been introduced called "Triangle of Life" in which people are recommended to stay next to heavy objects and furniture. Considering the high importance given to the correct sheltering in this study, the limitations and advantages of both advices are explored and an attempt has been made to identify one of them as the appropriate advice with regard to Iran's situation. For these purposes both advices are analysed briefly and compared to each other considering their application, the extent of people whom each advice is more appropriate for them, simplicity in transferring concepts, and the probability of reducing casualties and injuries. Based on the results and observations, it was revealed that "DCH" could still be regarded as a better option to recommend people of what to do during earthquakes.

Keywords:
"Drop, cover, and hold on"; "Triangle of life"; Earthquake safety; Proper sheltering

1. Introduction

Drop, cover and hold on (*DCH*) has been suggested as one of the most reliable, simple and easiest approach that is used for teaching public on earthquakes [1], see Figure (1). In this advice, it has been taught to people that when they feel the earthquake, they have to drop down to their knees on the floor in order to maintain their balance (Drop), find an appropriate place such as under a sturdy table, and to take shelter next to the interior walls (Cover) (a wall that has not got open space in its back). In the next step, (Hold on), one should hold on to something to maintain protection of his/her head and neck until the earth shaking stops. *"DCH"* has been taught in Iran as the "correct sheltering" in appropriate places. Appropriate place is where the probability of risk and damage is low. A nation-wide "Earthquake and Safety" drill is held in November each year in all schools in Iran based on *"DCH"* advice.

In the last decade, another advice, called the "Triangle of life" [2] has been introduced as places under rubbles that have been created due to the collision of ceiling with heavy objects regarded as safe places during the earthquakes. This idea was distributed through an email in 2004 to a massive number of people which made the *USA* Red Crescent responsible to reply [3]. Afterward, several feedback and comments were made to it. One of them considers that the "Triangle of life" advice makes several wrong assumptions [4]:

1) Buildings always collapse and crush all furniture inside;
2) Residents can always anticipate how their building might collapse and identify the location of survivable void spaces; and
3) During strong shaking, people can move to a desired location. However, many experts agree that in a rare case that a building collapses, residents inside will not be able to anticipate the location of

Figure 1. Taking shelter under the desk as one of the main steps in "DCH".

void spaces nor move to them during the strong shaking before the collapse.

"Triangle of life" has received a wide range of reactions in Iran. Examples include the publication of its translated version in a book called "Triangle of ife" [5], as well as publishing an article on the same subject in some news websites [6].

This paper aims to make a comparison and contrast between the *"DCH"* and "Triangle of life" advices as well as to illustrate their similarities from the scientific point of view. It is also intended to propose an appropriate advice for sheltering during earthquakes with regard to Iran's situation.

2. "DCH" and "Triangle of Life" Advices

In *"DCH"*, for the behaviour during earthquakes, it is recommended that: [7-11]:

- If one is inside the building, he/she should sit on the ground after taking some steps, then has to move to an appropriate place such as under a table and grab its feet and try to prevent the table to be removed from his/her head. If there is not any table or any other things by which one could take shelter, he/she may sit next to the interior wall (where there is no open space behind it) and put the knees on the floor and crunch on the other knee and protect his/her head and neck with ones hand and arms. This should be continued until the tremors stop. After the earthquake, the person should leave the building without any haste and with attention to what is going on around him/her;
- If one is in his/her bed and is awaken by the earthquake shaking, he/she should not move and has to put a pillow on his/her head and neck in order to protect them;
- If one is in a car driving, he/she should guide the car to the right side of the road or street and stay there, away from the bridges, electrical poles, and cables until the shaking stops;
- If one is in a lecture hall, he/she should crunch down on the floor and protect his/her head and neck with their hands and arms;
- If one is in an open space, he/she should try to get away from the buildings, electrical poles and other objects that may fall down on them, as shown in Figure (2). He/she should sit on the ground and protect their head and neck with their arms and hands.

Figure 2. Correct sheltering in an open space according to "DCH" advice.

More than half of the earthquake injuries are resulted from non-structural objects, i.e. fall of heavy or sharp objects, throwing pieces of broken glasses, embarrassments of people and pushing into each other, falling from the stairs and other similar issues.

There are minor differences observed in recommendations that are presented, however, in general, the above mentioned points are emphasized in most of these cases.

In "Triangle of Life", it is recommended [2]:

- Not to take shelter under the desk or a table, because it can cause the death during earthquakes;
- Curl up in fetal position in an earthquake;
- If in the bed during an earthquake, simply roll off the bed;
- If one cannot easily escape by getting out of the door or window, then he/she should lie down and curl up in a position next to a sofa or large chair;
- Do not shelter under doorway;

- Never go to the stairs;
- If possible, get near the outer walls of buildings or outside them. It is much better to be near outside of the building rather than the interior sides;
- If inside the vehicle, one should get out and sit or lie down next to his/her vehicle.

The recommendations in the "Triangle of life" advice assumes that the building collapses into a pancake model and there will be empty spaces created next to the heavy objects and this is when the ceiling has fallen.

As it can be seen, there are different recommendations in these two advices, some of which is even contrary to each other.

3. Application of "DCH" or "Triangle of Life"

Considering the above mentioned, it can be resulted that unless a building is collapsed completely, the *"DCH"* advice is a better choice than "Triangle of life", because it can better protect the person who is under the threat of the non-structural elements in the building. In this case, the "Triangle of life" not only threats the lives of people but also puts them under the menace of probable dangers. However, when the building experiences serious structural collapses and the ceiling falls down, two following situations can be predicted:

1) The structure is made of brick, and mud without any steel or concrete skeleton. This structure, will turn into a rubble of brick and mud and triangle spaces will not be created next to the heavy objects. If the people are in first floor and have enough time to exit, the best choice could be to leave the building. In other case, with regard to the fact that the masonry materials are lighter than the concrete (depends on heaviness of the roof), the possibility of breaking the sturdy tables are less than the structural concrete and therefore, the chances for people's survival is more. Hence, in this kind of structure, the *"DCH"* advice can be more useful than "Triangle of life";
2) The structure is either steel or concrete and there is a possibility of creating triangle spaces in buildings which have been collapsed in a pancake shape by falling of the ceiling on the heavy and condensed objects. In this situation, the *"DCH"* recommendations are not applicable, because it is assumed that the heaviness of the ceiling crushes in all tables, sofa or beds along with those people who have taken shelter in or under them and can produce great damages and losses. Therefore, "Triangle of life" recommendations can survive people due to creating void spaces next to the heavy and condensed objects and survivors can be found in spaces large enough for a human within the collapse debris called 'Survivable Void Space'. This can be as large as an adult, or in the case of small children and infants, a very small space.

4. Comparison of the "DCH" and "Triangle of Life" Content Transference

In *"DCH"* approach, it is recommended clearly and directly to people to maintain their calmness and drop to their knees on the ground without any panic and go under a table or a sturdy object and keep the legs of the table until the shakings stop, or sit next to the wall and protect their head and neck with their arms. These recommendations are very direct and understandable to people and due to the simplicity of the contents, it is also possible to transfer them easily.

In "Triangle of life", sheltering next to heavy objects is also a simple and direct recommendation and asking to shelter next to the refrigerator or big boxes is very understandable by people and even seems simpler than the *"DCH"* advice. However, there is a problem in transferring these contexts. In fact, the weakness lies in the message itself. Although people are recommended to shelter next to the heavy and condensed objects, but at the same time, there is no guarantee in which side of the objects, the "Triangle of life" might take place. If the direction of objects with possible void spaces is identified beforehand, then issues regarding columns in buildings and their behaviour in the earthquakes should be taught to people in advance. In other words, each person should have sufficient information about the technical situation of his/her building in order to be able to presume where the "Triangle of life" might be formed. This will make the messages more complicated and mostly not understandable to all.

In addition, there are not many heavy objects located in a building. Therefore, it is possible that it takes a long time for a person to reach them and this can cause that person to fall and make him/her injured. Also if the earthquake force is enough in the horizontal direction, the object that the person has sheltered next to it, can move and fall on him/her. This can also be hazardous in case of sheltering next to a car, because the car can move and crush that person [12]. Considering these points, taking shelter next to the condensed and heavy objects should be

accompanied with a series of technical and specific information which makes the transference of the messages very complicated.

5. Classifying the Target Groups

The "*DCH*" and "Triangle of life" advices can be compared based on the ratio of the numbers of people that these advices are suitable to protect them against earthquakes. In this section, an attempt has been made to estimate the ratio based on earthquake intensity.

5.1. Classifying the Target Groups Considering the Intensity of an Earthquake

The target group here is referred to those who experience one of the mentioned situations. They can be classified based on an earthquake parameter called intensity. The earthquake intensity scale is used in order to express the degree of people's feeling from the tremors and damage of buildings in any part of the earth surface. Therefore, an earthquake with a specific magnitude (for example 6) can produce various intensities in the earth surface based on its distance to earthquake epicentre as well as other conditions. Table (1) illustrates the intensities in *EMS*98 Scale [13]. It is a rough guide to the degrees of the *EMS*98 Scale.

Seismologists usually prepare intensity maps after major earthquakes in order to show the degree of damages in the earthquake prone areas. These maps show the attenuation of intensity in various geographical directions, see Figure (3). Based on the intensity maps, the degree of tremors, that people living around the earthquake epicentre have experienced, can be revealed.

According to Table (1), individual's reaction to earthquake may be started from Intensity *III*. In other word, people who experience earthquakes with intensities more than *III* may be under the threat of inappropriate reactions or structural and non-structural damage. Intensities between *III*-*VII* may cause cracks in the building, but would not result in a structural

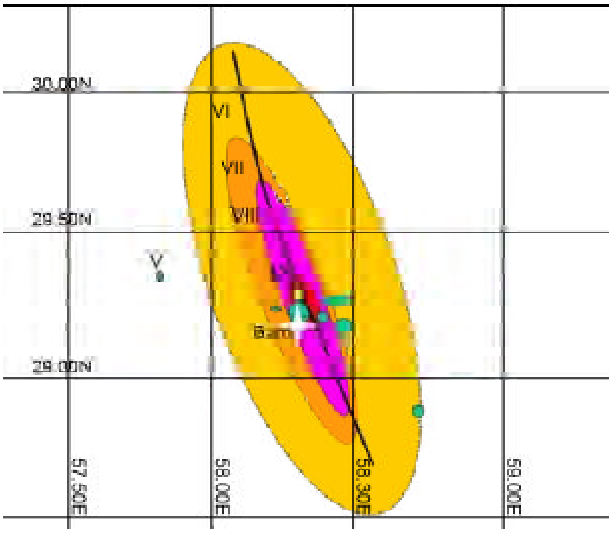

Figure 3. The Iso-intensity Map for Bam Earthquake [14].

Table 1. The intensities in EMS98 scale (simplified of [13]).

I. Not felt	Not felt, even under the most favourable circumstances.
II. Scarcely Felt	Vibration is felt only by individual people at rest in houses, especially on upper floors of buildings.
III. Weak	The vibration is weak and is felt indoors by a few people. People at rest feel a swaying or light trembling.
IV. Largely Observed	The earthquake is felt indoors by many people, outdoors by very few. A few people are awakened. The level of vibration is not frightening. Windows, doors and dishes rattle. Hanging objects swing.
V. Strong	The earthquake is felt indoors by most, outdoors by few. Many sleeping people awake. A few run outdoors. Buildings tremble throughout. Hanging objects swing considerably. China and glasses clatter together. The vibration is strong. Top heavy objects topple over. Doors and windows swing open or shut.
VI. Slightly Damaging	Felt by most indoors and by many outdoors. Many people in buildings are frightened and run outdoors. Small objects fall. Slight damage to many ordinary buildings; for example, fine cracks in plaster and small pieces of plaster fall.
VII. Damaging	Most people are frightened and run outdoors. Furniture is shifted and objects fall from shelves in large numbers. Many ordinary buildings suffer moderate damage: small cracks in walls; partial collapse of chimneys.
VIII. Heavily Damaging	Furniture may be overturned. Many ordinary buildings suffer damage: chimneys fall; large cracks appear in walls and a few buildings may partially collapse.
IX. Destructive	Monuments and columns fall or are twisted. Many ordinary buildings partially collapse and a few collapse completely.
X. Very Destructive	Many ordinary buildings collapse.
XI. Devastating	Most ordinary buildings collapse.
XII. Completely Devastating	Practically all structures above and below ground are heavily damaged or destroyed.

rupture. The collapse of ceiling is also expected with intensities more than *VII*. Therefore, people who experience intensities more than *VII* might face the collapse of buildings.

Based on this, the target groups and those who will be under the threat of earthquake risk, can be classified as follows:

Group 1: People who experience earthquakes with intensities *III* to *VII*. This group are basically under the threat of non-structural elements. Therefore the recommendations of *"DCH"* can reduce the risk of damage to them. For this group, the "Triangle of life" advice does not apply.

Group 2: Those who experience earthquakes with intensities *VII* and more and live in wood structures or buildings made of steel or concrete which the collapse type will be in pancake shape. For this group, the use of "Triangle of life" advice can be useful rather than *"DCH"*.

Group 3: People who experience earthquakes with intensities *VII* or more and live in structures without skeleton or structures which collapse in a different way to the pancake shape. For this group, none of the advices of *"DCH"* and "Triangle of life" could be useful.

Note that there are many people who experience earthquakes with intensities *VII* and more, but their structures do not collapse during the earthquake. In this study this group are classified in groups 2 and 3 based on their structural types.

5.2. Estimating the Ratio of People Whom "Triangle of Life" Advice Is Likely to be More Appropriate for Them

In case the place of an earthquake is assumed randomly, the frequency ratio of total people in groups 2 and 3 to group 1 can be assessed by estimating the area which covers the intensity more than *VII* (*S*2) to the area under coverage of *III* to *VII* (*S*1) in different earthquakes. This is illustrated as *R* (Ratio) in this paper. It is worth mentioning that due to the assumption that the place of earthquake is random, issues such as population and building densities and other factors are assumed homogenous.

$$R = \frac{\text{Frequency of Groups 2 and 3}}{\text{Frequency of Group 1}} = \frac{\text{the area more than VII intensity}}{\text{the area between III and VII intensity}} = \frac{S2}{S1}.$$

In order to estimate *R*, the iso-intensity map should be available; however, practically the isoseismic maps are not prepared for all earthquakes. The map usually will be illustrated for the earthquakes that result in major casualties and damage. An example is Figure (3), which has been conducted for Bam Earthquake. In these maps, the areas which are affected by intensity *IV* and less are not illustrated. For solving this problem, the experimental attenuation models can be employed for estimating the earthquake intensity by using the magnitude and distance from the epicentre. For Iran, this equation is developed by Zare and Memarian [15], see Eq. (1).

$$I = 1.175M - 0.014X - 0.227\ Ln\ X \quad (1)$$

In Eq. (1), the earthquake intensity is in *EMS*98 Scale, *M* is the moment magnitude of the earthquake, and *X* is epicentral distance (in Kilometres). With regard to this equation, for each earthquake with a specific magnitude, the produced distance can be estimated by various intensities. Using Eq. (1), however, can only provide a relative result of the intensity but it covers the aim of this study which is the overall estimation of the relative number of people who encounter the disaster.

Considering Eq. (1), the distance for various intensities can be estimated for a specific earthquake, however in this study, these distances are (as well as the *S*1 and *S*2 levels) calculated for chosen earthquakes that occurred during the period of 30 years between 1970 and 2000 in Iran. In Figure (4), the frequency of earthquakes with magnitudes greater than 4 is illustrated. The total number of the earthquakes in this range is 4740. This frequency has been provided by using the earthquakes database of the International Institute of Earthquake Engineering and Seismology (*IIEES*) [16].

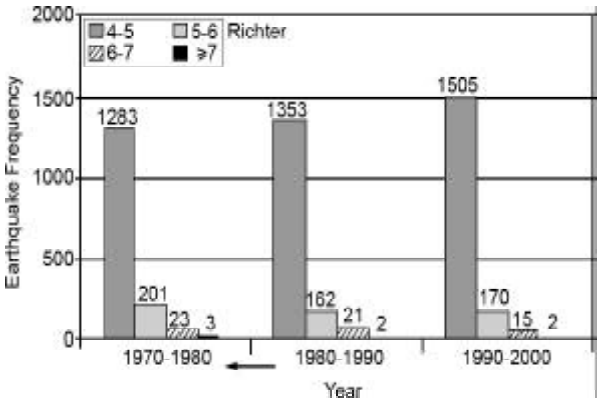

Figure 4. Frequencies of earthquakes with different magnitudes in Iran during 1970-2000.

Figure (5) shows a schematic design of the iso-intensity *III* and *IV* curves which are produced for an earthquake occurred along the assumed fault. In this figure, the iso-intensity curve is shown by symmetrical ovals comprising small and big diameters. The big diameter is stretched along the earthquake fault. In Figure (5), half of small diameter of the iso-intensity curves *III* and *VII* has been shown with letters *a* and *b* respectively and half of the length of fault which has been active in the earthquake, is illustrated with letter *c*.

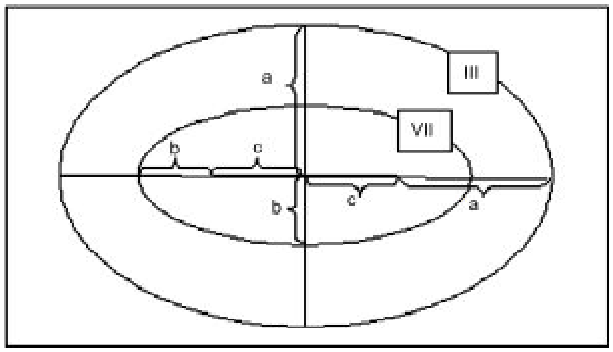

Figure 5. Geometrical parameters related to the iso-intensity III and VII ovals around the fault.

Based on Eq. (1), the distance of iso-intensity curve is almost equal from each section, and half of the big ovals diameters of the *III* and *VII* intensities are $a+c$ and $c+b$, respectively.

In Figure (6), the areas between intensities III and *VII* (the area related to people group 1, *S*1) and more than *VII* (areas related to people groups 2 and 3, *S*2) are shown.

The ratio between two mentioned areas can be calculated through Eq. (2):

$$R=\frac{S2}{S1}=\frac{[b(c+b)]\pi}{[a(c+a)]\pi-[b(c+b)]\pi}=\frac{bc+b^2}{ac+a^2-b-b^2} \quad (2)$$

In this equation, *a* and *b* are half of the small diameter of the iso-intensity curves *III* and *VII*, respectively and *c* is half of the length of the activated earthquake fault.

Using Eq. (1), *a* and *b* can be estimated for earthquakes with different magnitudes. These quantities for earthquakes with magnitudes more than 4 is calculated and given in Table (2).

For example, in an earthquake with magnitude 7, the maximum distance for intensity *III* is 282 Kilometers, however, in the same earthquake, the *VII* intensity will be produced in 31.5 Kilometers. In other situation, in an earthquake with a magnitude of 5, the maximum distance for intensity *III* is 126.83. In this earthquake, the intensity *VII* is not produced.

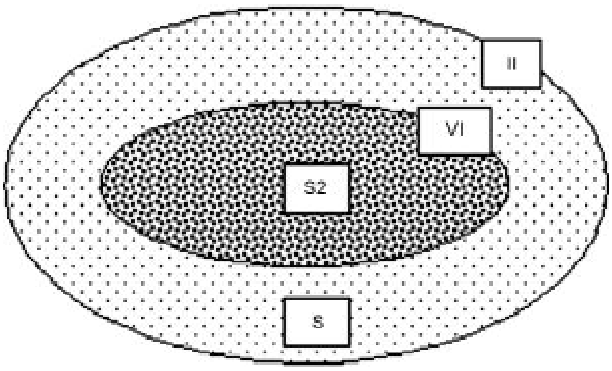

Figure 6. Areas between intensities III and VII (open dotted lines, S1) and more than VII (condensed dotted lines, S2).

Table 2. Maximum distance of the iso-intensity III and VII curves from the faults (*a* and *b*) due to earthquakes with different magnitudes (distances are in Kilometers).

Intensity/Magnitude	4	5	6	7	8
III (*a*)	56.12	126.83	203	282	362
VII (*b*)	0	0	0	31,5	97

In Table (3), by using the "Iran Earthquakes Databank" (*IIEES*) for the last 30 years [16], the number of earthquakes (*N*) is shown in different intervals of magnitude. Also in this Table, the average number of *a* and *b* is given for the limits of magnitude (*a* and *b*).

For obtaining the overall estimation of each parameter *a* and *b*, in a way that the number of earthquakes is considered in each magnitude intervals, Eq. (3) can be used:

$$a_m=\frac{\sum_{i=1}^{n} a_i\times N_i}{\sum_{i=1}^{n} N_i} \quad (3)$$

In which a_m is the average distance of intensity *III* (with regard to the number of earthquakes), a_i is the

Table 3. a and b quantities for various magnitudes.

Magnitude	Average Magnitude	Number (N)	*a* (III)	*b* (VII)
4-5	4,5	4141	90.37	0
5-6	5.5	533	154.57	0
6-7	6.5	59	242.24	0
7-8	7.5	7	321.57	62.5

distance of intensity *III* in magnitude interval of *i*, N_i is the number of occurred earthquakes in *i* magnitude intervals during 30 years 1970-1999 and *n* is the required limits. The same equation is true for calculating b_m. Based on this equation, a_m and b_m are equal to 100,95 and 0,09 Kilometers, respectively. Similar to Eq. (2), and assuming that *C* is equal to 10*km*, the amount of *R* is calculated as 0,000083 ($1/R = 12021$).

With regard to this, it is observed that if the population density is assumed randomly considering the place of earthquake occurrences, the number of people in group 1 (people in areas with intensities between *III* and *VII*) will be around 12000 times than the total number of people in groups 2 and 3 (located in areas with intensities more than *VII*).

6. Discussion and Conclusions

With regard to the above mentioned issues, the characteristics of both *"DCH"* and "Triangle of life" advices are summarized in Table (4).

As it can be observed in this table, the *"DCH"* is a simple and transferable advice that can be considered appropriate for people in group 1. The weakness of *"DCH"* is that it does not seem very useful for groups 2 and 3. The "Triangle of life" is also apparently a simple advice which covers the target population in group 2. However, since a person should have information about the technical situation of his/her building in order to be able to anticipate, where the "Triangle of life" would be formed, this will make the messages more complicated. The "Triangle of life" can also bring harmful consequences to group 1 (which the numbers are 12000 times than groups 2 and 3). It can be noted that many buildings in Iran, especially in rural areas, are made of brick and mud without skeleton, and therefore a high percentage of people will be placed in groups 2 and 3. This will therefore, make this advice less important than *"DCH"*. It has to be mentioned that if the ceiling has not collapsed, then the *"DCH"* recommendations can protect people from dangers, such as getting injured while running out of the buildings, and by falling objects or broken glasses. In cases when the reverse happens and the building is collapsed, the "Triangle of life" advice seems more successful in surviving lives.

Recognizing these conditions is not possible for people who are experiencing an earthquake. Additionally, it is also difficult to recommend two sets of "sheltering" guidelines to people with considering the statements mentioned in this paper. Furthermore, the number of the people who do not experience the roof falling and for them *"DCH"* advice is more appropriate are 12000 times of the rest of the people. As a result, the *"DCH"* advice can then be proposed as a more useful instruction that one can follow to protect himself/herself during earthquakes.

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Table 4. The characteristics of "DCH" and "Triangle of Life" advices.

Advice	Implication	The Amount of People in Target Groups	Way of Transference of Messages to People	Possibility Access to Reducing Casualties, Injuries and Damage
DCH	It is an appropriate advice if structural rupture has not occurred.	12000 times "Triangle of life" Advice.	Simple	*Very much*, if the damage is due to the non-structural elements. *Minor*, when the ceiling falls.
Triangle of Life	When the structure is skeleton or wooden and there is a structural rupture.	0,000083 times "DCH" Advice.	Simple	*Very minor*, if the damage is due to the non-structural elements. *Average*, in cases when the ceiling falls.

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