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What are the factors that determine the origin of cracks?

¿Cuáles son los factores que inciden en el origen de las grietas?

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This article deals with the problem of cracks, their meaning, characteristics, differences, and similarities with fissures are made known. Having clarity in the above, it begins by identifying the place and structures where the cracks appear, as is done the evaluation and measurement, and with this last one speaks of their importance. The origin of the cracks is influenced by several factors, including physical and external factors, which allow the analysis of the origin of the crack. Finally, the consequences and the methods used to minimize the appearance of cracks are evaluated in order to provide guidance on their effects and possible solutions.

Keywords: Cracks, factors, fissures, measurement, structures

Este artículo aborda el problema de las grietas, se da a conocer su significado, características, diferencias y similitudes con las fisuras. Teniendo claridad en lo anterior, se empieza por identificar el lugar y las estructuras donde aparecen las grietas, como se realiza la evaluación y medición, y con esto último se habla de su importancia. En el origen de las grietas inciden varios factores, dentro de los cuales se encuentran factores físicos y externos, los cuales permiten el análisis del origen de la grieta. Por último, se evalúan las consecuencias y los métodos que se usan para minimizar el surgimiento de las grietas a fin de orientar sobre sus efectos y posibles soluciones.

Palabras clave: Estructuras, factores, fisuras, grietas, medición

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Introduction

This article gives to know the different causes by which cracks can originate in the constructions, considering the external or physical factors that affect, which are the most common. In the same way, it is shown how to identify them, either by their dangerousness, their size, and the point where they are, among others (Xingwu et al., 2016).

A possible solution to minimize these phenomena is also presented (Khaliq & Basit, 2016). It also talks about the consequences that are caused when there is no adequate control over these pathologies.

Knowing about these structural problems has gained much interest in recent years due to the large collapses and damage that have occurred in buildings by this situation. It is observed that a large part of the problem lies in misinformation and mismanagement of construction methods.

The cracks

Among the different damages that are presented in the buildings, there is one in particular called crack. It is a problem that affects many of the houses in Bogotá (Colombia) and of which people know very little and has much greater importance due to its size.

What is a crack?

In the field of civil engineering a crack *is a deep opening with a width greater than 1 mm* (Construmática, 2017) that emerges uncontrollably in the sections of a structure affecting the building material, tend to divide the building element in two, which weakens the strength of the building causing structural damage (refer to damage generated within the building).

Usually, these types of openings go through the entire section when they originate inside and out, making them even more dangerous.

The main and most important places where these openings can be produced are in the pillars (columns), beams, walls, in the different plates, among others. These places are crucial for the building to maintain its shape, strength, and stability.

Cracks can be sorted by width and can have different degrees of hazard, among which are mild, moderate and severe.

Mild grade cracks or also called fissures *are those in which their width is less than 5 mm, and have a zigzag or diagonal appearance* (Navarrete, 2016). In general, these fissures do not represent a danger to the construction.

Moderate grade cracks *are those in which their width is 5 mm to 1 cm* (Navarrete, 2016), can be expanded longitudinally until they become elongated. Depending on their location they may or may not represent a danger to the building (Fig. 1).

Figure 1. Crack in the house (Gonzalez, 2017).

Severe grade cracks *are those in which their width exceeds 1cm. These cracks represent a great danger to people and therefore their presence requires the evacuation of houses. They are characterized because they expose the materials and are very large* (Navarrete, 2016). This kind of openings leaves the structure with a great instability so that at any moment it can collapse causing great disasters (Fig. 2).

Figure 2. Earthquake-induced cracks (WebAdictos, 2017).

When defining the cause that gave rise to the crack, care must be taken due to the confusion that can occur between fissure and crack. This is to prevent misunderstandings when solving the damage or giving information.

What's the difference between fissure and crack?

In principle, an opening is a space that is generated within a construction element (walls, columns, plates, etc.). According to the Encyclopaedia Broto of pathologies in construction (Broto, 2006), a fissure is an opening that appears on the surface of a building element and is less than 1 mm wide.

Also *Cracks can be a stage prior to the appearance of a crack, they also have similarities in terms of the symptoms they suffer, but they lead to a different origin and evolution* (Broto, 2006). This suggests the relationship between fissure

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and crack. Fissures are one of the symptoms of concrete pathology (Silva, 2016).

Charles Broto (Broto, 2006) proposes the subdivision of fissures into two groups:

- **Reflection of the support**: It is produced when there is a constructive discontinuity by a joint (the space where *the glue* is poured between the bricks, Fig. 3).

Figure 3. Crack in concrete wall (Arbsuwan, 2017).

- **Inherent to the finish**: In this case, it is spoken superficially that the fissure in this group is formed by retraction in the mortar (Fig. 4).

Figure 4. Brick repairs (*Brick Repairs*, 2017).

With the previously mentioned, the difference between fissure and crack can be described in a group of characteristics which are: width, origin (the reflection of the support or inherent to the finish) and evolution (Fig. 5).

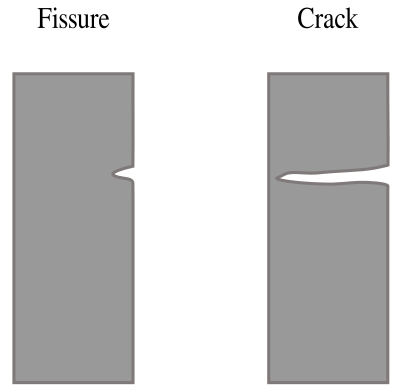

Figure 5. Fissure and crack comparison.

Places where cracks appear

Cracks usually appear in all housing. The places where these appear are associated to a specific zone, which is commonly located in the walls. People can all see some kind of crack or fissure in homes, but there is always a tendency to associate cracks with a wall. However, the walls are not the only places where these pathologies appear, so below are described the places where it is possible to appreciate the appearance of a crack.

- **Cracks in the walls**: They are the most common, originated in the cladding of the wall and extended to reach a very significant length, so much so that it can cause irreparable damage to the construction.

When the wall is without a cladding, the brick or block and the mortar are exposed, which due to certain environmental factors cause the appearance of cracks and fissures. This allows us to see that the bricks or blocks and mortar are not exempt from the presence of cracks, giving them the ability to accommodate this problem (Fig. 6).

Figure 6. Cracks in the wall (Ayala, 2017).

• **Cracks in tiles, veneers or tiles**: When openings occur in these types of construction elements they tend to be fissures because of their width. In spite of this, they can have a great extension. They are common, but not very noticeable.

Cracks may be present in the joints of the above elements. It is very rare, and the majority of the cases that arise are due to improper use of the additive element (Fig. 7).

Figure 7. Wall tiling (Baldwin, 2017).

• **Cracks in columns, beams**: As they are constructive elements that can be made of both concrete and wood, we will focus only on those that are made of concrete.

Like walls, columns and beams tend to present cracks, caused by different factors that we will mention in the next section. They can cause great disasters because they are the support of the structure in the case of porches and combined systems (Fig. 8).

Figure 8. The PSOE denounces that the columns of the laundry have cracks (Arteixo, 2014).

Assessment and measurement

As mentioned earlier, cracks are very common manifestations in structures that are easy to recognize. In order to identify them, the place where they appear, the direction and the size of the crack are examined.

The cracks have a development time and it is necessary that from the moment in which the crack was observed a follow up is made to the crack, a measurement of its length and width, and of its layout.

Initially, an analysis of the structure must be carried out: pathologies, settlements, characteristics of the land, old uses of the land, etc. Also, make a detailed description of the fissure or crack with the help of some elements that will facilitate its analysis.

• **Fissure meter**. It is an element that allows measuring the thickness of the fissure (Fig. 9).

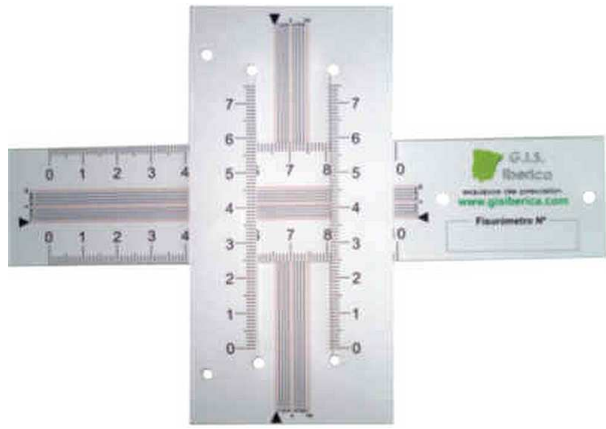

Figure 9. Fisurometer (GIS Iberica, 2017).

• **Witnesses of plaster or glass**. They allow us to observe the evolution and life of cracks and fissures, to know if they are still active or to place them preventively and to know the development of the crack, to know if its evolution is slow, fast or not progressing (Fig. 10).

Figure 10. Stucco witnesses (Pagina, 2017).

• **Thread deformometers**. They allow monitoring the changes between the distance of two points. Generally used in the measurement of small cracks (Fig. 11).

With the help of the elements mentioned above, it is possible to know the thickness, direction of the crack, and make comparisons at different dates, which helps to determine in which direction the forces that cause the appearance of this pathology are being performed to analyze

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Figure 11. Thread deformometers (Sisgeo, 2017).

them and see the possible causes. They should also be taken to a general plan of the structure to have a better overview of its behavior.

Crack data should be evaluated with the help of measurements of turns, inclinations, and collapses. To make these measurements are used devices such as dianas, optical plummets, level staff, precision photographic levels, inclinometers, among others.

Thanks to these methods, it is able to address possible problems with the structure, classify the crack and its evolution, in order to obtain a solution and/or evaluate the risk it causes in the structure.

Importance of knowing about cracks

Cracks in recent years have taken a very significant role in assessing the state of a building, because if they are present means that something harmful is happening in the structure, although not all mean a risk to the construction.

This is why it is important to have knowledge about cracks because this allows us to identify how dangerous they can be and also the steps to follow from the moment they appear. But not only to know how dangerous they are but also to anticipate in advance that they may arise.

Crack generating factors

Physical factors

The physical factors that influence the generation of cracks and affect the structures are the following:

- Humidity expansion.
- Dilation.
- Retraction.

Humidity expansion. This problem mainly affects ceramic materials (vaults, bricks, and other ceramic pieces) as they have an inverse characteristic to the one in concrete. Concrete starts humid and loses this humidity, whereas ceramics start dry because its elaboration process is carried out in ovens at a high temperature, and its humidity generates a balance with the humidity of the environment.

It is a phenomenon in which the ceramic expands while it gains humidity *in the first month can expand half of the total, in the first week half of all of the month, and on the first day, half of all of that week. Ten years later, it still has something to expand* (De Miguel, 2017a). However, this process can be accelerated if moisture is initially captured by irrigation or immersion to avoid major consequences on the structure. As a reference, we have expansion in the ceramic in the order of 0.5 mm/m if the irrigation has not been done before the assembly.

If the brick or ceramic is potentially expansive and has not been watered enough, it begins to slowly increase in size, until it becomes trapped in the building elements because it cannot expand further, and to increase its tension causing the bursting of the same, throwing pieces and with the ability to cause personal injury.

The most characteristic fissure of this problem is the vertical fissure near the edges as shown in Fig. 12.

Figure 12. Dilatation by humidity (De Miguel, 2017a).

Dilatation. All physical bodies in the face of a variation in temperature change their size. If the temperature increases the physical body increases its size if the temperature decreases the body shrinks. The same happens with structures, if the building increases its temperature, its dimensions would also increase (Fig. 13).

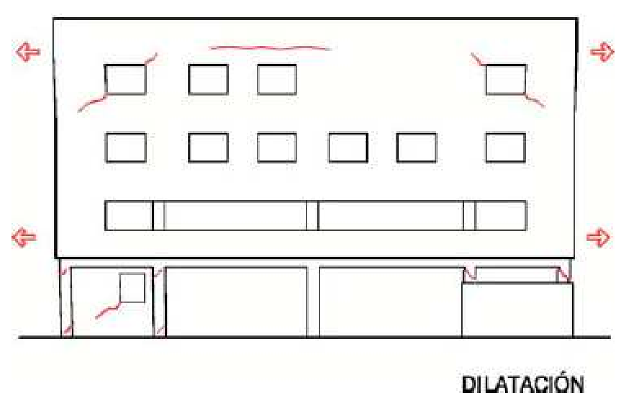

Figure 13. Dilatation (De Miguel, 2017b).

As a reference value, we have 0.01mm/m for each ^{o}C increase. To understand it better we have the following example: *an element of 25 m long that oscillated its temperature from winter to summer, in sunny front, in 80^{o}C, would increase its length in 2 cm, displacing each one of its ends 1 cm towards outside* (De Miguel, 2017b).

As the length increases and the building does not have the capacity to resist such effects, the supports of the construction are curved and this generates maximum flexions at its ends and a zero flexion in the middle, thus generating cracks in the structure.

To be able to identify if the cracks were caused by thermal action we look at the part where the cracks appear, the most usual is that they appear at the ends as they are weakened by the openings of the structure. If the supports are made of concrete, diagonal cracks appear above and below as shown in the lower left part of Fig. 13.

Retraction. Retraction consists of the loss of water suffered by the concrete in its drying process, generating a balance between humidity and air, causing the volume of the concrete to decrease. As a reference we have *0.1 mm/m after seven days, 0.3 mm/m in a year. For example, an element 30 m long would shorten in one year, about 1 cm* (De Miguel, 2017b) (Fig. 14).

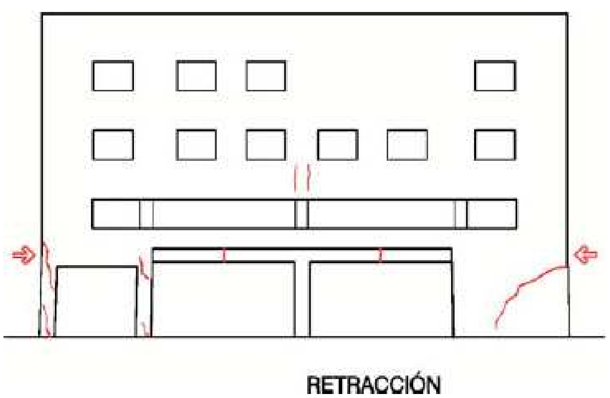

Figure 14. Retraction (De Miguel, 2017c).

When there is pressure, the concrete is the one that fractures, where it does not necessarily involve the rest of the construction elements. However, it is structural damage and should be cataloged as self-injury.

The crack is generated similar to dilatation, where flexions are generated in the supports, which causes it to bend and form cracks as shown in Fig. 14.

The appearance of cracks by retraction occurs mostly in the lintels, since when this tries to reduce its length and fails to move the elements that support it, it generates resistance and therefore traction, causing the appearance of cracks in that segment. The same happens in other parts of the structure, as in the supports, but it is more usual in the lintels.

External factors

Among the external factors we have: differential settlement, expansiveness, horizontal action, deflection, overloads, fires, construction clumsiness.

Differential settlement. The land where the buildings are built undergoes different changes depending on the factors that affect it. One of the factors is the loads generated by the construction itself. These loads cause sinking in the ground and therefore the footings (López, Guaita, Ayuga, & Cañas, 2000), but can occur in different parts of the building, and this is what is called differential settlement (Fig. 15).

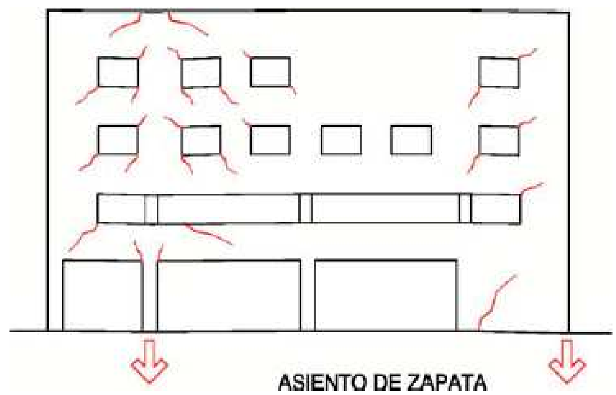

Figure 15. Footing settlement (De Miguel, 2017d).

The damage caused by the settlements are the cracks, usually these cracks are inclined and directed to the point where is the settlement, have an arc shape and appear at all levels of the construction.

Expansiveness. This effect occurs when buildings are located on clay soil. The clay manifests certain humidity and when it increases, due to the filtration of the water in the ground, it increases its volume producing a push upwards of the footings (Fig. 16).

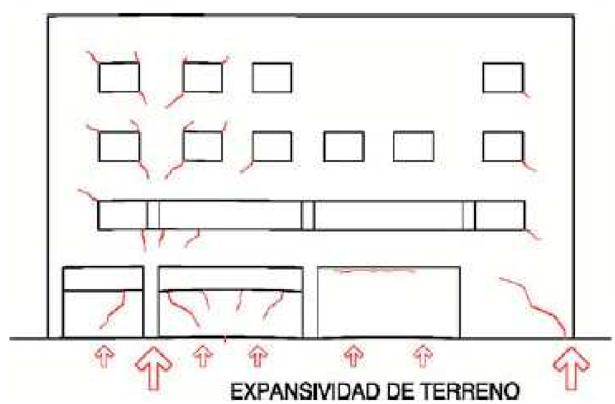

Figure 16. Terrain expansiveness (De Miguel, 2017e).

Due to the expansiveness, local cracks originate and can be more vertical. They are more difficult to control as they can start from the supports (columns and beams). In some cases, the expansion is so great that it does not generate a push but breaks the foundation.

Horizontal action. When we speak of horizontal action we refer to the seismic movement of the soil. As we know these movements can come in any direction, and their

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duration is not much but produces significant disasters. They can also cause cracking in buildings that can be mild or severe (Fig. 17).

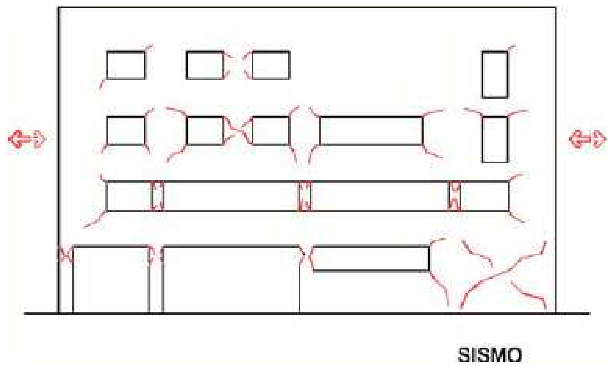

Figure 17. Earthquake (De Miguel, 2017f).

The slight cracking is when the telluric movement is minimal, and small cracks are originated more than everything around the spans and not very significant.

On the other hand, we have severe cracking, which is given in the form of a cross. It is usually between the supports and the walls and has an extensive length. This type of cracking is very significant as it weakens the building to a point of collapse. They generally occur in the weakest points of the building.

Deflection. When we speak of the deflection factor we are referring to the punctual and distributed loads of the building. The different constructive elements are influenced by the loads causing them to suffer a flexion and therefore a deformation. This occurs when the capacity to support the weight of the building itself and everything in it is exceeded (Fig. 18).

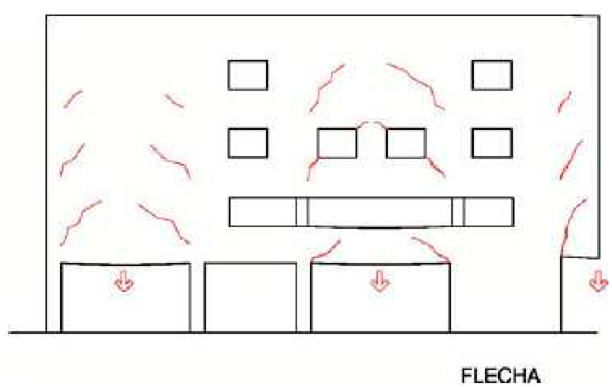

Figure 18. Deflection (De Miguel, 2017g).

The deflection produces an aggregation that is given from top to bottom. To identify if the building suffers this situation must be tested before it is inhabited, placing loads in strategic locations and verifying that it can withstand them without flexion in the columns, beams, and plates.

Construction clumsiness. When constructing a building there can be several errors which can cause cracking. These errors can be of calculations, plans, or work among others. Although they do not occur very frequently, it can occur either because of the strength or efficiency with which the building materials are handled.

Cracks caused by construction errors can be seen in the joining and bonding of the materials, for example in the mortar between the blocks (Fig. 19).

Figure 19. Basement kits carbon wall repair fiber (Code, 2017).

Vibrations. Other agents that cause the appearance of cracks in the constructions are vibrations. These are produced either because around the building there is the passage of heavy vehicles or because they are being made buildings in neighboring areas.

Cracks caused by vibrations do not represent a significant risk, they can be treated as aesthetic damage. Although if they occur in strategic points such as pillars or those elements that are of support, they can be of great danger.

Consequences, minimization and reparation of cracks

Consequences of cracks

Cracks cause significant damage to structures. In spite of the underestimation they are given, they have a considerable impact in the field of construction. For that reason analyzing the consequences that can generate provides valuable information and preventive at the same time.

Whether it's construction settlement, imperfections in the materials used to build the home, or damage caused by the environment, cracks can become a big problem.

As for housing in Colombia, there are cases in which government-supplied housing has cracks causing severe damage to construction, as can be seen in cases such as Metrovivienda in Cúcuta (Colombia) in 2015, where people living in nearly 80 apartments in the urbanization had to go through the fear that their homes would collapse. In terms of repairs, the construction company carried out repairs on four occasions, but cracks were still appearing (Tiempo, 2015a).

There are also cases of cracks caused by adjacent construction. In 2013 began the construction of a work in the locality of Usaquén (Bogotá, Colombia), in which the excavations generated cracks in the houses surrounding the work. In addition, the damage caused by this construction went so far as to issue eviction notices for the serious damage caused (Tiempo, 2015b).

Returning to social housing, some of these located in San Luis, Ciudadela Parque de la Roca and El Trigal, La Aguadita in Suba, Villa de Los Alpes de San Cristóbal, the apartments of these houses collapsed after three years. The main signs show that it was due to cracks in the structures, the window sills, the walls, and the roof. More than a thousand families were affected by the cracking and collapse of their homes (Gómez, 2000).

In the case of earthquakes, there are documented cases that show how they cause cracks and thus bring their consequences. Internationally we can speak of Tanaguarenas (Venezuela), where the cracks that Misión Vivienda had were enlarged by an earthquake of magnitude 4.5 in which the inhabitants expressed fear that the structure would collapse (Nacional, 2017).

From the previous cases, it can be seen that cracks are a matter of care. They can lead to many tragedies, and their identification and management can prevent them. Facing the cracks and taking precautions is something that we must all do no matter how unnecessary it sometimes seems so that the cases mentioned above do not happen.

How can the appearance of cracks in a home be minimized?

There are many ways to prevent the manifestation of cracks, but the method used depends on what type it is and what causes it. The most common ways in which this type of pathology can be reduced are the following:

Gaskets. This method is to be used to avoid contraction and retraction cracks, either caused by humidity or temperature changes. It will help the construction element to have a slight movement so as not to have a collision with another element, *It should not exceed 30 times its thickness, the ideal would be between 25 cm and 40 cm thick* (Grados, 2017).

Use of construction norms. In many of the cases in which cracks are present, it is because construction masters (mostly in low socioeconomic strata) do not adequately follow the building rules, and omit steps that are necessary to minimize the emergence of these. This situation can be corrected by making known the rules governing the construction of buildings and making proper use of them.

It is possible to add, in addition, the horizontal action, that is to say, to include also the cracks that arise by the horizontal action which can be minimized with exact handling of the norm NSR-10 (Colombian Earthquake Resistant Norm of the year 2010).

Adequate study of soils. Another of the great factors originating in the cracks is the type of soil in which the buildings are built since if a soil study is not carried out in which it is evident with which it is treated, differential seats, expansive terrain and deflection can be presented.

To avoid this it is possible:

- The main thing is to carry out the study of soils.
- If this study cannot be done, the procedure to follow is to start digging and look at the level at which the most stable soil can be found.
- Also where the footing is going to be made, with a type of mass (rammer) the soil can be compacted to give greater stability, and that these footing does not suffer a downward displacement.

Quality and proper use of materials. When speaking of the proper use of materials, it refers to the fact that when mixing and everything related to the preparation of materials to start building, the established proportions must be managed. An example, in this case, is the preparation of the concrete. The concrete should not be too watery (it should not have a large amount of water), only the amount of water necessary to obtain the greatest resistance.

The quality will be related to the fact that the materials are not fractured, do not present a deterioration and their expiration date is not expired.

How can the cracks be repaired?

Even with precise handling and compliance with all parameters, there may be a case of cracks in the building.

Therefore, the following parameters must be taken into account:

- What surface is it located on? This refers to whether the location is on concrete, wood, brick, etc.
- Where it is located. That is to say, it is in the roof, the wall, the floor, among others.
- What kind of crack is it? In this parameter, it is established how dangerous it is, its thickness, its location, and its depth.

It is clear that if it is already very dangerous, it should not be handled so easily. It is necessary to have the opinion of an expert to know the steps to follow.

Techniques to repair cracks.

- **Resin injection**. The procedure is very simple, as its name indicates, is to inject a type of glue called resin which has fast drying properties and is used in small cracks.
- **Crack cover putty**. The mixture is obtained by combining white cement with water. It should be free of lumps and is applied by filling the space of the opening.
- In the market it is possible to obtain very easily adhesives for this type of pathologies, they are very varied and do not present complexity at the time of using them.

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• For larger cracks can be used bands cover cracks. At the moment of using them, plaster is needed in order to have a better fixation.

• Depending on the type of material the necessary products can be found. For example, in bricks and cement, putties are used, and anticorrosive products are used if any steel material is exposed.

• Finally, even simpler, only the use of paint is necessary to be able to cover them.

Conclusions

Crack research provides more detailed and complete information on behavior, occurrence, factors, evaluation, repair, and how to minimize the problem of cracks. This must be within the reach of the whole society in order to achieve a basic level of knowledge about this problem since it is a structural problem that depending on its size and shape can generate great damage and usually affect homes and/or structures.

There are several types of cracks and fissures that must be differentiated to achieve an optimal evaluation of each of them. The evaluation is carried out with the use of some methods and devices, all with great utility and ease of use. The best known and used are the fissure meter and the plaster or crystal witnesses. Each of them helps to identify the direction, size, and activity of the crack.

The appearance of cracks can be observed in all construction systems of the structure without exception. These systems can be affected by factors external to the structure (earthquakes and overloads, among others), or physical factors (humidity, retraction, and dilatation), causing cracking and deterioration of the structure.

Nowadays, in most of the constructions that exist both on the slopes and in some vulnerable and humble areas of Bogotá (Colombia), it can be observed that the population does not carry out soil studies, either because of ignorance or because they do not have the money to do so. This is a very important factor that generates the appearance of cracks when not taken into account. The study of soils is a requirement according to the Colombian Earthquake Resistant Norm, for that reason all structure either of a floor, two or more must be evaluated and constructed on the basis of the norm. This would help that a great number of structures be safer and resistant, and additionally, they are structurally strong in front of an earthquake or external factors to itself.

In order to minimize cracks, the Colombian Earthquake Resistant Norm must be taken into account, which is the basis of all construction and allows for the construction of a structure that adjusts to the terrain and takes into account any factor that may generate cracks.

If some of the suggestions for minimizing cracks are not taken into account, and a crack is generated, it must begin to analyze which repair technique is most appropriate so that the structure is not greatly affected.

Additionally, it could be analyzed and investigated in the future that other solutions, tools, and methods can be taken into account to evaluate and minimize the appearance of cracks and their repair.

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