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Application of the GUT technique in pathological manifestations in reinforced concrete structures and their corrections

Aplicação da técnica GUT em manifestações patológicas de estruturas de concreto armado e suas correções

Aplicación de la técnica GUT en manifestaciones patológicas de estructuras de hormigón armado y sus correcciones

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Abstract
Reinforced concrete is a constructive system widely used around the world. However, this constructive technique has constant failures and pathological manifestations. These problems may occur due to possible design flaws, mistakes in structural design, failures in execution process, as well as the lack of maintenance. Many researchers reported the high incidence of steel corrosion in reinforced concrete structures as one of the main pathological manifestations in all over the world. There is a lack of decision-making as to which manifestations need to be repaired urgently and which ones can wait for future repairs without aggravating the damage to the structure. Given this scenario, this work aimed to carry out a visual inspection in a reinforced concrete building, identifying its pathological manifestations and classifying these with the decision-making tool GUT (Gravity, Urgency, and Tendency). During the inspection generalized corrosion was identified in the reinforced concrete structural parts: slab, beams, and columns. By applying the GUT tool, it was possible to identify the priority of repairs on slabs, beams, and columns. The pathological manifestations observed were possibly caused by the incorporation of aggressive agents at the time of building the residence.
Keywords: Reinforced concrete structures; Pathological manifestations; Steel corrosion; GUT technique; Pathologies in reinforced concrete.

Resumo

O concreto armado é um sistema construtivo amplamente utilizado ao redor do mundo. No entanto, esta técnica construtiva tem muitas falhas e manifestações patológicas. Estes problemas podem ocorrer devido a possíveis falhas de projeto, erros no dimensionamento estrutural, falhas no processo executivo, assim como falta de manutenção adequada. Muitos pesquisadores apontam para grande incidência de corrosão no aço do concreto armado, como uma das principais manifestações patológicas encontradas em todo o mundo. Existe uma falta de ferramentas na tomada de decisão quanto às manifestações patológicas, que precisam ser reparadas urgentemente e quais podem aguardar reparos futuros sem agravar o estado de degradação estrutural. Neste cenário, este trabalho visa fazer uma inspeção visual em uma estrutura de concreto armado, identificando suas manifestações patológicas e classificando estas com a ferramenta de tomada de decisão GUT (Gravidade, Urgência e Tendencia). Durante a inspeção, Corrosão do aço; foi identificada corrosão generalizada em várias partes da estrutura: lajes, vigas e pilares. Aplicando a metodologia GUT, foi possível identificar a prioridade no reparo de lajes, vigas e pilares. Possivelmente, as manifestações patológicas observadas foram causadas pela incorporação de agentes agressivos durante a construção da residência.

Palavras-chave: Estruturas de concreto armado; Manifestações patológicas; Corrosão do aço; Técnica GUT; Patologias em concreto armado.

Resumen

El Hormigón armado es un Sistema constructivo usado em todo el mundo. Sin embargo, esta técnica constructiva tiene muchos defectos e manifestaciones patológicas. Estos problemas pueden ocurrir debido a posibles defectos de proyecto, errores en lo cálculo estructural, fallas em la construcción e la falta adecuada de mantenimiento. Numerosos investigadores señalan una alta incidencia de corrosión en el hormigón armado, como una de las principales manifestaciones patológicas encontradas em todo el mundo. Hay una falta de herramientas em la toma de decisiones sobre las manifestaciones patológicas, cuáles necesitan ser reparadas con urgencia y cuáles pueden esperar reparaciones futuras sin agravar el estado de degradación estructural. En este escenario, este trabajo tiene como objetivo realizar una inspección visual de una estructura de hormigón armado, identificando sus manifestaciones patológicas y clasificándolas con la herramienta de toma de decisiones GUT (Gravedad, Urgencia y Tendencia). Durante la inspección, se identificó corrosión generalizada en varias partes de la estructura: losas, vigas y columnas. Aplicando la metodología GUT, fue posible identificar la prioridad en la reparación de losas, vigas y pilares. Posiblemente, las manifestaciones patológicas observadas fueron causadas por la incorporación de agentes agresivos durante la construcción de la residencia.

Palabras clave: Estructuras de hormigón armado; Manifestaciones patológicas; Corrosión del acero; Técnica GUT; Patologías en hormigón armado.

1. Introduction

Reinforced concrete is the most used construction system in countries like Brazil. Its structural characteristics provide greater load capacity, a fact that makes this structural system widely used in any region of the country. However, even though it is a highly diffused technology, it still presents serious problems concerning design and execution aspects. This constructive system requires high levels of attention regarding the fulfillment of construction processes since faulty projects or executive techniques can put the aesthetic and structural aspects of the building at risk (Chemrouk, 2015; Baiburin, 2017). Another factor that contributes to the emergence of pathologies in construction is the high construction cost and the search for quick completion of buildings, contributing to failures in execution, as well as non-compliance with national technical standards (Dórea et al., 2010).

Dórea et al. (2010) performed a study of the main pathologies in old buildings. In their research they verified that steel corrosion in the structures is one of the main flaws found. Besides that, Helene (2002), Angst (2018) and Bueno et al. (2019) also affirm this predominant incidence of steel corrosion as the main manifestation pathological in reinforced concrete structures.

One of the reasons that make rebar is susceptible to corrosion is due to a process called carbonation of the concrete. This process directly affects concrete's durability and strength. This phenomenon consists of the diffusion of carbon dioxide in the hardened concrete passing through the capillary pores or cracks, which reacts with calcium hydroxide ($Ca(OH)_2$) and precipitates calcium carbonate (CaCO3). This precipitation reduces the concrete pH, leaving the steel bar unprotected and allowing steel corrosion to occur (Chemrouk, 2015; Bonić et al., 2015).

The corrosion process results in the precipitation of ferrous hydroxide ($Fe(OH)_2$) which occupies a larger volume than

that occupied by the original steel. The precipitated corrosion product exerts a gradually increasing pressure on the surrounding concrete until it cracks and propagates from the reinforcement to an adjacent concrete surface following the line of the underlying reinforcement. This may end up with concrete spalling and detaching completely, leaving the reinforcement bar uncovered and speeding up the corrosion process (Chemrouk, 2015; Bonić et al., 2015).

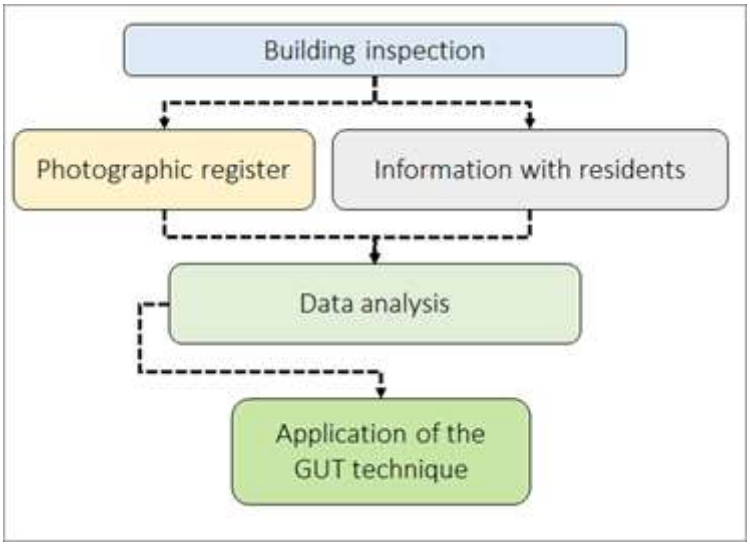
With many cases of pathological manifestations due to steel corrosion in reinforced concrete, the need to identify the source causing these pathologies is evident. In addition, there is a need for a management tool that makes it possible to assist in decision making regarding the order of urgency and severity of pathological manifestations in the structures, determining their correction priority. Braga et al., (2017) and Braga et al., (2019) made use of the GUT technique for decision making in different scenarios, obtaining satisfactory results. The GUT analysis tool takes into account the Gravity (G), the Urgency (U), and the Tendency (T) of the detected problems. Thus, this work aimed to carry out an inspection in a single-family residence, identifying the pathological manifestations, finding its possible causes and using the GUT tool for decision-making.

2. Materials and Methods

This work is a case study, with quali-quantitative analyzes that provide support for its conclusions and objectives (Koche, 2011). Vedovatte et al. (2021) complements that the application of a practical case study with the use of scientific, technological and instrumental knowledge related to the field of knowledge aims to report and expand the knowledge channel of the object of study.

To the present study was carried out based on visual inspections and photographic records of the reinforced concrete structure of a single-family residence constructed in 1983 in the city of Passo Fundo, state of Rio Grande do Sul, Brazil. The single-family residence is composed by a reinforced concrete structure consisting of slabs, beams and columns, with a built area of 530 m^2. The residence has a total of four floors, the ground floor being used as a garage, and the rest as the living area of the residence. The many stages of this work were structured according to the flowchart of activities shown in Figure 1.

Figure 1: Flowchart of activities.



Source: Authors.

The methodology of visual inspections is recurrent in research of pathology analysis in structures (Morais et al., 2020; Silva Júnior et al., 2020; Cirino et al., 2020). The flowchart (Fig. 1) was organized with the following steps: inspection of the

building, photographic record, and survey with the residents about the building's history. Then, the data collected were analyzed for the structuring of the GUT analysis tool. Subsequently, based on the structure's conditions, possible correction and repair for the pathologies were suggested.

The guidelines presented by Kepner and Tregoe (1981) were used to apply the GUT technique, using three levels of assessment: Gravity, Urgency, and Tendency, as shown in Table 1, Table 2, and Table 3, respectively.

Table 1: GUT Matrix for Gravity classification.

Degree	Definition of degree	Score
Total	Risk of death, unrecoverable impact with excessive loss of performance, very high financial loss.	10
High	Danger of lesion to users, recoverable damage to the environment and building.	8
Average	Risk to user's health occasioned by degradation of systems, reversible environmental damage, average financial loss.	6
Low	No health risk to users, low environmental degradation, necessity to substitute some systems, low financial loss.	3
None	No risk of health or physical, minimal deterioration of the environment, no financial damage.	1

Source: Adapted from Verzola et al., (2014).

When analyzing the gravity of the pathological manifestation, it should be noted whether the current situation of the structure poses a risk to the lives of the users, so the highest score should be considered. However, if it does not present any risk to the life and health of the users or the deterioration of the building, then the lowest score for the condition is considered.

Table 2: GUT Matrix for Urgency classification.

Degree	Definition of degree	Score
Total	Immediate event, necessity of interdiction of the property without extra deadlines.	10
High	Event in the imminence of happening, urgent intervention.	8
Average	Adversity expected soon necessity to intervene rapidly.	6
Low	Initiation of an incident, intervention still in planning.	3
None	Unexpected adversity, but necessary monitoring for future maintenance.	1

Source: Adapted from Verzola et al., (2014).

When verifying the urgency of the pathology, its need for correction must be analyzed concerning the time spent without proper care. Thus, if immediate correction is necessary, the highest score for this condition must be distributed. On the other hand, if the manifestation does not present urgency in its correction, then the lowest score must be adopted.

Table 3: GUT Matrix for Tendency classification.

Degree	Definition of degree	Score
Total	Immediate progress of manifestation could have worsening rapidly.	10
High	Evolution of the situation about to occur.	8
Average	Medium-term evolution.	6
Low	Possible long-term evolution. It may occur. Delay situation.	3
None	Situation stabilized, without evolution case.	1

Source: Adapted from Verzola et al., (2014).

Tables 1 to 3 presented the classification according to GUT Matrix for Gravity, Urgency and Tendency classification. These tables are extremely important for the case study carried out.

Finally, when observing the tendency, the condition of the structure should be checked: if nothing is done to correct it, will it get worse? If the answer is yes, the highest score should be considered. On the other hand, if it is not going to get worse, then the lowest score should be considered.

After analyzing the conditions and distributing the scores for Gravity, Urgency, and Tendency, the values must be multiplied (G x U x T), totaling the final score for each situation, the highest scores are defined as the critical and priority conditions for repairs. Moreover, corrective measures must be presented for the pathological manifestations observed. Other researchers have also used the GUT matrix to verify structures and to aid in decision-making. Many authors confirm the efficiency of the technique in identifying priorities for decision making (Verzola et al., 2014; Brito, 2017; Braga et al., 2019).

3. Results and Discussion

3.1 Identification of pathological manifestations in the structure

When the analysis was performed, several defects were found in the in the structural elements of reinforced concrete. For each anomaly identified, evaluations were made using the GUT methodology, as well as a description of the possible causes for it to occur. In the garage, several anomalies were observed in the reinforced concrete columns. The columns showed detachment of pieces of concrete, compromising its section integrity. The structures had a high degree of corrosion, as shown in Figure 2.

Figure 2: Reinforced concrete column on the ground floor of the building.

Source: Authors.

High deterioration of the steel in the structure was observed in Figure 2, as well as the loss of concrete section integrity of the structural part. In these conditions, the structure presents a serious risk of collapse, mainly because these are the columns of the ground floor, that support the load of other floors.

The non-observation of reinforcement covering is one of the main causes of pathological manifestations in buildings since the lack of this thickness of protection can facilitate the attack of chemical agents. These agents can attack the concrete, reducing its pH and accelerating the steel oxidation. Over time, this process will expand the section of steel, causing cracks and loss of section (Moreira, 2015; Silva Júnior et al., 2020). In this way, Brazilian Standard NBR 6118 (ABNT, 2014) stablish a minimum reinforcement cover considering environmental aggressivity. The column reinforcement covering wasn't uniform and didn't meet the standard's requirements.

Thus, it is understood that the pathological manifestation occurred due to one or more of the following conditions: (I) the aggressor may have been incorporated in the concrete kneading process, or in the used steel bar, which was already in the corrosion process; (II) the concrete porosity, which can be related to the high water-to-cement ratio, and could result in the loss of compressive strength (Braga, 2010; Cirino et al., 2020). The reduction of compressive strength can facilitate the cracking process by overload (Carasek, 1996; Chaves, 2009; Cirino et al., 2020); or finally, (III) the wrong dosage rate of the concrete, not being enough to resist the building load, causing cracks and failure by the reduction of the compressive strength. The characteristics described for this situation, as well as their evaluation using the GUT technique, can be observed according to the summary presented in Table 4.

Table 4: Pathological Manifestation analyses and GUT Matrix of Figure 2.

Figure	Pathological Manifestation	Parking column	
2	Advanced corrosion of the column reinforcement.	**Possible causes:**	• Concrete with high permeability and / or high porosity. • Incorporation of aggressive agents in the concrete matrix. • Low compressive strength.
		Origin:	• Project. • Execution.
		Symptoms:	• Loss of concrete adhesion. • Spalling of the concrete. • Steel corrosion. • Loss of reinforcement and concrete section.
		GUT: 640	**G**= 10; **U**= 8; **T**= 8.

Source: Authors.

As shown in Table 4, the identified pathological manifestation recognized an assessment: Total for Severity (10 points), high for Urgency (8 points), and high for Tendency (8 points), totaling a GUT of 640 points. As for the origin of the defects, it can be said that they could originate from the execution, because they did not pay attention to the correct cleaning of the parts, remove and identify the corrosive agents in the steel before its insertion in the structure; or due to project, in this case, considering that the structural calculator does not correctly consider the concrete strength Fck.

In the roof slabs of the ground and first floors, pathological manifestations like those previously described were found. The steel of the slabs had a high degree of oxidation. The conditions described can be seen in Figure 3.

Figure 3: Reinforced concrete slab of the building.

Source: Authors.

During the inspection, was verified crumbling of concrete, in addition to the rebar's exposure in large regions of the slab (Fig. 3). And was observed that the concrete did not meet the national standards - NBR 6118 - regarding the minimum reinforcement cover for reinforced slabs, which is 25 mm in moderately aggressive conditions (urban areas) (ABNT, 2014). In

this way, the defect may have been caused by design, if the blueprints didn't present the minimum reinforcement cover specification or by execution, if were not used spacers during concreting process. Table 5 presents the possible causes and symptoms observed in the slab.

Table 5: Pathological Manifestation analyses and GUT Matrix of Figure 3.

Figure	**Pathological Manifestation**	**Parking column**	
3	Advanced corrosion of the slab's reinforcement.	**Possible cause:**	• Concrete with high permeability and / or high porosity. • Incorporation of aggressive agents in the concrete. • Insufficient reinforcement coverage.
		Origin:	• Project. • Execution.
		Symptoms:	• Loss of concrete adhesion. • Spalling of the concrete. • Steel corrosion. • Loss of reinforcement and concrete section.
		GUT: 1000	**G**= 10; **U**= 10; **T**= 10.

Source: Authors.

The classification of the manifestation regarding the GUT technique was Total for Gravity (10 points), Total for Urgency (10 points), and Total for Tendency (10 points), totaling a GUT of 1000 points, according to Table 5. These considerations were based on the fact that the slab is submitted to bending moment as its main acting stress, therefore rebar steel is under tension conditions, and any failure of rebar may result in structural failure. This is proving to be in an advanced degradation's state; therefore, evaluations of Gravity, Urgency, and Tendency was considered Total for all the situations.

The lack of concrete cover thickness in reinforced concrete is one of the main failures in civil construction, and this is the main cause of the steel corrosion (Liberati et al., 2014; Medeiros et al., 2017; Silva Júnior et al., 2020). Besides that, other factors may be responsible for the appearance of these manifestations, such as the high porosity of the concrete matrix due to the high water-to-cement ratio and the presence of aggressive agents incorporated into the concrete matrix at the time of the structure's execution, with were already explained earlier.

Moreover, the excessive humidity is another factor that could have caused these manifestations, due to the lack of waterproofing of the slab; however, this possible cause was ruled out of the investigation because the slab was not exposed to natural weathering and the residents did not clean the slab with excess water. Another factor to be considered is that no leak points were identified in the pipes.

As with the other elements of the building, widespread corrosion was observed in the structures of the support beams on the first floor, as seen in Figure 4.

Figure 4: Reinforced concrete beams of the building.

Source: Authors.

In a visual inspection of the beams structure (Fig. 4), cracks were observed along with the element, as well as detachment of the concrete in the places of greater corrosion of the steel. In the beams, as well as in the columns, no flaws were observed concerning the reinforcement covering, therefore, in this regard, they were following the coverage guidelines of the national standard NBR 6118 (ABNT, 2014). The other pathological manifestations can be seen according to Table 6.

Table 6: Pathological Manifestation analyses and GUT Matrix of Figure 4.

Figure	**Pathological Manifestation**	**Parking column**	
4	Advanced corrosion of the beam's reinforcement.	**Possible cause:**	• Concrete with high permeability and / or high porosity. • Incorporation of aggressive agents in the concrete. • Low concrete resistance to compression.
		Origin:	• Project. • Execution.
		Symptoms:	• Loss of concrete adhesion. • Spalling of the concrete. • Steel corrosion. • Loss of reinforcement and concrete section.
		GUT: 800	**G**= 10; **U**= 10; **T**= 8.

Source: Authors.

The classification of the manifestation regarding the GUT technique was Total for Gravity (10 points), Total for Urgency (10 points), and Total for Tendency (8 points), totaling a GUT of 800 points, according to Table 6. The considerations to be taken for the pathological manifestations observed in the beams are likewise those carried out in the previous structural elements.

Based on the observations, due to the generalized corrosion of the structural elements, possibly the main cause is the insertion of aggressive agents into the structure during the construction period of the building, which may come from the

materials used, such as steel bars already in a state of corrosion and/or water or the sand used in the concrete mixture with the presence of contaminants. The insufficient covering of the reinforcement in the slab, the porosity of the structural parts, and the insufficient compressive strength of the concrete was considered as aggravating factors, that is, they helped in the process of deterioration of the structure but were not considered as the main cause.

As these are the same pathological manifestations both in columns, as in beams and slabs, the technique for correcting the structures to be used is similar for the different structural elements analyzed. The first step to correct the pathologies is to analyze the straining efforts on each structural part, to determine the support load of the structure's shoring. In the analysis of the GUT tool, it is possible to observe the need for priority correction for the slabs (1000 points), beams (800 points) and in sequence the columns (640 points).

4. Conclusion

Reinforced concrete structures are highly resistant to buildings load and provide good living conditions for users. However, as much as this technology is widely used all over the world, problems related to the durability and degradation of the structure are still observed. The main pathologies causes are failures in the design specifications, in the structural design, in the lack of building's maintenance and mistakes in the construction process.

Regarding the pathological manifestations presented in this work, there is a strong indication that the main cause of pathologies in the building was still incorporated in the construction process, possibly in the incorporation of contaminated materials in the structure, which may be steel, water, the sand used in the concrete, or even the way that the structures were executed that inserted the aggressor agent in concrete pieces. Like any pathology, its occurrence can often be silent, taking years to present its effects visually, be it in the form of a crack or even the splintering of pieces of concrete. The GUT methodology proved to be a tool capable of indicating the priority points in the structure, pointing out the aspects of gravity, urgency, and the tendency to cause greater damage to the building and its residents.

For future work, the authors suggest the use of the technique and methods used in other pathological manifestations in order to consolidate them as a methodology in the field of analysis, hoping to contribute with other works in the same area of study.

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References

Angst, U. M. (2018). Challenges and opportunities in corrosion of steel in concrete. *Materials and Structures*, 51(1). https://doi.org/10.1617/s11527-017-1131-6

Associação Brasileira De Normas Técnicas – ABNT (2014). *NBR 6118: Projeto de estruturas de concreto – Procedimento*. Rio de Janeiro, 225p.

Baiburin, A. K. (2017). Errors, Defects and Safety Control at Construction Stage. *Procedia Engineering*, 206, 807–813. https://doi.org/10.1016/j.proeng.2017.10.555

Bonić, Z., Ćurčić, G. T., Davidović, N., & Savić, J. (2015). Damage of Concrete and Reinforcement of Reinforced-Concrete Foundations Caused by Environmental Effects. *Procedia Engineering*, 117, 411–418. https://doi.org/10.1016/j.proeng.2015.08.187

Bueno, G. M., Carneiro, E. R., Ramão, A. C., Piva, G. O., & Tutikian, B. F. (2019). Evaluation of reinforced concrete structural durability in the post-occupation phase - A case study in Novo Hamburgo/RS. *REM - International Engineering Journal*, 72(1), 9–16. https://doi.org/10.1590/0370-44672018720040

Braga, N. M. T. (2010). *Patologias nas construções: Trincas e fissuras em edifícios*. (Doctoral dissertation, Monografia – (Especialização em Construção Civil) – Universidade Federal de Minas Gerais, Belo Horizonte).

Braga, I. C., Diógenes, A. G., Ribeiro, F. R. C., & Brandão, F. da S. (2017). Application of gut matrix in the inspection of a heritage construction in fortaleza-ce. *Revista De Engenharia e Pesquisa Aplicada*, 2(3), 1–12. https://doi.org/10.25286/repa.v2i3

Braga, I. C., Brandão, F. da, Ribeiro, F. R., & Diógenes, A. G. (2019). Application of GUT Matrix in the assessment of pathological manifestations in heritage constructions. *Revista ALCONPAT*, 9(3), 320–335. https://doi.org/10.21041/ra.v9i3.400

Brito, T. F. D. (2017). *Análise de Manifestações Patológicas na Construção Civil pelo Método GUT: estudo de caso em uma instituição pública de ensino superior*. (Trabalho de Conclusão de Curso, Universidade Federal da Paraíba - UFPB)

Carasek, H. (1996). *Aderência de argamassas à base de cimento portland a substratos porosos: avaliação dos fatores intervenientes e contribuição ao estudo do mecanismo da ligação*. São Paulo, 285.

Chaves, A. M. V. A. (2009). *Patologia e Reabilitação de Revestimentos de Fachadas*. Universidade do Minho. (Doctoral dissertation, Dissertação de Mestrado).

Chemrouk, M. (2015). The Deteriorations of Reinforced Concrete and the Option of High Performances Reinforced Concrete. *Procedia Engineering*, 125, 713–724. https://doi.org/10.1016/j.proeng.2015.11.112

Cirino, M. A., Oliveira, B. B., Pereira, S. L., Cordeiro, S. B., Morais, J. M., Silva, E. M., & Barboza, E. N. (2020). Avaliação das manifestações patológicas das edificações do departamento de engenharia de alimentos da Universidade Federal do Ceará. *Research, Society and Development*, 9(7). https://doi.org/10.33448/rsd-v9i7.4424

Dórea, S. C. L., Santos, D. de G., Sales, A. T. C., & Silveira, P. M. D. (2010). Avaliação patológica da estrutura de concreto armado e dos componentes de uma edificação construída em 1914. *Scientia Plena*. https://www.scientiaplena.org.br/sp/article/view/317.

Helene, P. (2002). *Manual para reparo, reforço e proteção de estruturas de concreto*. São Paulo: Pini.

Kepner, Charles H.; Tregoe, Benjamin B (1981). *O administrador racional*. São Paulo: Atlas.

Koche, J. C. (2011). *Fundamentos de metodologia científica*. Petrópolis.

Liberati, E. A., Leonel, E. D., & Nogueira, C. G. (2014). Influence of the reinforcement corrosion on the bending moment capacity of reinforced concrete beams: a structural reliability approach. *Revista IBRACON De Estruturas e Materiais*, 7(3), 379–413. https://doi.org/10.1590/s1983-41952014000300005

Medeiros, M. H., Rocha, F. C., Medeiros-JUNIOR, R. A., & Helene, P. (2017). Corrosion potential: influence of moisture, water-cement ratio, chloride content and concrete cover. *Revista IBRACON De Estruturas e Materiais*, 10(4), 864–885. https://doi.org/10.1590/s1983-41952017000400005

Morais, J. M., Cirino, M. A., Lôbo, J. M., Silva, E. M., Barboza, E. N., Oliveira, B. B., & Souza, J. H. (2020). Análises das patologias construtivas: Estudo de caso em uma escola na cidade de Juazeiro do Norte, Ceará, Brasil. *Research, Society and Development*, 9(7). https://doi.org/10.33448/rsd-v9i7.4421

Moreira, C. (2015). *Realcalinização de estruturas de concreto carbonatado com utilização de gel saturado de solução alcalina*. Dissertação (Mestrado). Curso de Engenharia Civil, Goiás: Universidade Federal de Goiás, 122p.

Silva Júnior, L. A., Ribeiro, I. V., & Medeiros, S. D. (2020). Levantamento técnico dos problemas patológicos dos edifícios da UEMG - Unidade de João Monlevade: efeitos e condutas de intervenções. *Research, Society and Development*, 9(8). https://doi.org/10.33448/rsd-v9i8.4889

Vedovatte, R. M., Vedovatte, V. G., Torrecilhas, A. R., Pianucci, M. N., Dos Santos, K. T., Negrão, F. A., Sella, M. R., Kanashiro, R. O., Chiavelli, H. G. R., & Galvão, R. B. (2021). Estudo de caso de aulas práticas aplicadas no curso de tecnologia em segurança do trabalho na modalidade EaD / Case study of practical classes applied in the course of technology in workplace safety in distance education. *Brazilian Journal of Development*, *7*(4), 39422–39430. https://doi.org/10.34117/bjdv7n4-415

Verzola, S. N., Marchiori, F., & Aragon, J. O. (2014). Proposta de lista de verificação para inspeção predial x urgência das manutenções. *XV Encontro Nacional De Tecnologia Do Ambiente Construído*. https://doi.org/10.17012/entac2014.300