Development of the Building Information Modeling (BIM) certification process for application in tailings dams raised downstream: CUB-e GEO

Desenvolvimento do processo de certificação Building Infomation Modeling (BIM) para aplicação em barragens de rejeito alteadas à jusante: CUB-e GEO

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ABSTRACT
Building Information Modeling is a topic of major relevance. In Brazil, the federal government, through Decrees 9.983 (BRASIL, 2019) and 10.306 (BRASIL, 2020), established the implementation of the BIM BR Strategy and defined deadlines for the beginning of the use of technology in the country, being the first step from January 2021. Another topic that has gained visibility in recent years was the monitoring of tailings dams due to disruptions in the state of Minas Gerais. It was established that, to guarantee the safety of a dam, the safest construction method is the downstream upgrading, being the object of study of the present research. With this, the main objective of the work is to expand the BIM CUB-e Certification Model (Gosling *et al.*, 2020) for application in downstream upgrading dam, and, thus, contribute to the development of a complete Brazilian certification model. which will attest to the capacity of a mining company using BIM, contributing to provide greater safety at the dams. Thus, the BIM CUB-e GEO Certification Model was developed, concluding that the BIM technology associated with tailings dams can contributes to safety, improving executive and monitoring processes, reducing the probability of failure associated with a tailing dam.

Keywords: Building Information Modeling, Certification, Civil Construction, Technology, Geotechnics, Tailing dam

RESUMO
A Modelagem da Informação da Construção, do inglês Building Information Modeling (BIM) é tema de maior relevância. No Brasil, o governo federal, através dos Decretos 9.983 (BRASIL, 2019) e 10.306 (BRASIL, 2020), estabeleceu a implantação da Estratégia BIM BR e definiu prazos para início da utilização da tecnologia no país, sendo a primeira etapa a partir de janeiro de 2021. Outro tema que ganhou visibilidade nos últimos anos foi o monitoramento das barragens de rejeito devido a rompimentos ocorridos no estado de Minas Gerais. Estabeleceu-se que, para garantia da segurança de uma barragem, o método construtivo mais seguro é o alteamento à jusante, sendo então o objeto de estudo da presente pesquisa. Com isso, com objetivo principal do trabalho é ampliar o Modelo de Certificação BIM CUB-e (Gosling *et al.*, 2020) para aplicação em barragens alteadas à jusante, e, dessa forma, contribuir para o desenvolvimento de um modelo de certificação brasileiro completo o qual atestará a capacidade de uma mineradora em utilização do BIM, contribuindo para prover maior segurança nas barragens. Dessa forma, desenvolveu-se o Modelo de Certificação BIM CUB-*e* GEO, concluindo-se que a tecnologia BIM associada à barragens de rejeito contribui para a segurança, melhorando os processos executivos e de monitoramento, reduzindo-se a probabilidade de falha associada à uma barragem de rejeitos.

Palavras-Chave: Building Information Modeling, Certificação, Construção Civil, Tecnologia, Geotecnia, Barragem de Rejeito

1 INTRODUCTION

The civil construction sector is constantly moving and improving, and the optimization of jobs to save time and money are one of the main objectives of the sector. The search for new tools and methodologies brings opportunities for innovation in the techniques used from planning to the execution of a construction, and it is in this scenario of constant innovation, that Building Information Modeling (BIM), is gaining more notoriety.

BIM is a technology that allows the integration of all stages of a construction, making it possible to provide in-depth information about all of them. This methodology includes a series of software that allows the integration of projects and data, providing a complete visualization of the work before it even begins to be executed. Thus, it was configured as a reliable base generator for conflict resolution and decision making throughout the life cycle of the structure (NATIONAL INSTITUTE OF BUILDING SCIENCES, 2015).

In Brazil two decrees were stablished to implement the use of BIM in direct or indirect execution of engineering works and services carried out by public agencies. The first one, number 9.983, of August 22, 2019, lays down the National BIM Dissemination Strategy in Brazil with the purpose of promoting an adequate environment for the use of this new technology, creating good conditions for this investment in the country and encouraging training of professionals in the field (BRASIL, 2019).

The second, decree number 10.306, of April 02, 2020, establishes that the Modeling of Construction information is implemented directly or indirectly in the engineering works and services carried out by the entities of the federal public administration. The realization of the use of this new technology will be make in stages from the year 2021 and according to the decree mentioned the last phase is schedule for 2028 when the management and maintenance of the enterprise must be developed or executed with the application of BIM (BRASIL,2020).

A field of civil engineering that has been very prominent in recent years is tailings dams. The main purpose of these constructions is to avoid environmental damage caused by mining. Its monitoring is important in view of the accidents that have occurred in recent years and, currently, it is done in an outdated way in view of the new technologies that are available in the middle of civil construction (MACHADO, 2007).

Giving importance to technological advances, it’s clear that the use of BIM in geotechnical constructions can bring numerous benefits to the area, helping significantly so that the monitoring of dams is done in a more precise way and so that these structures are increasingly safer. However, some obstacles in the implementation of this technology may occur due to the lack of qualified professionals, the lack of software and the incompatibility of files and the difficulty of adapting to the new way of working.

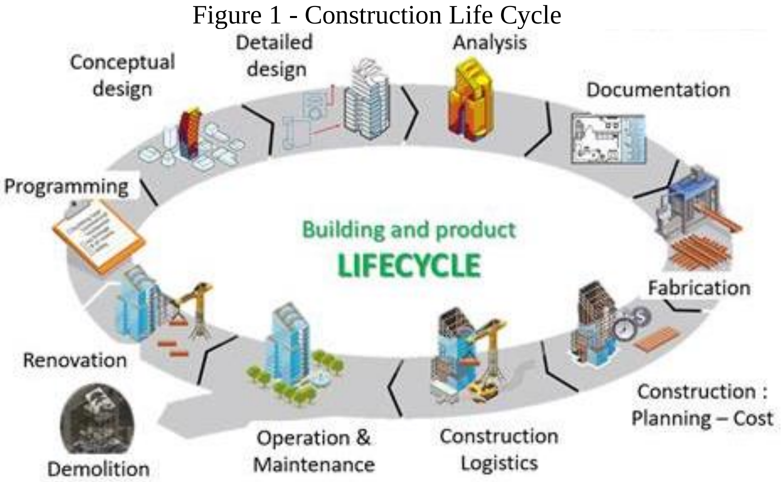
Considering this scenario of dissemination of BIM in Brazil and all discussions involving tailings dams, a certification process was necessary for companies that use this technology in dam constructions. This process will guarantee a seal for those who guarantee the necessary points in the analyzed parameters within the studied BIM dimensions.

2 THEORETICAL REFERENCE

2.1 BUILDING INFORMATION MODELING

BIM - Building Information Modeling - embrace from the conception of a building to its possible demolition, following its entire life cycle. It is a modeling technology and an associated group of processes for the production, communication and analysis of the construction model (EASTMAN, 2014). It involves technologies and processes that seek to integrate the various stages of a construction (Figure 1) avoiding problems of interference between areas (clash detection) and increasing the efficiency and quality of the construction (ANDRADE and RUSCHELL, 2009).

Figure 1 - Construction Life Cycle



Source: REHVA - Federation of European Heating (2020)

Therefore, BIM is a technology that allows greater detail, inter-collaboration between employees and disciplines in addition to enabling a broader vision plan, that is, being able to have an overview of what is being worked on, allowing for better error detection in preliminary stages.

2.1.1 BIM dimensions

2.1.1.1 1D – Protocols and Implantation

The first BIM dimension refers to the implementation of protocols in a country or organization. This dimension prioritizes the drafting of laws and contracts that determine the use of BIM in public works, among others. From this, it is possible to continue the drawings and make the project compatible (DARÓS, 2019).

2.1.1.2 2D – Graphic Representation

The second BIM dimension is responsible for representing the enerat plans, which are floor plans, sections and facades. In this model, traditional designs known for delivering drawings are enerat, which may have several inconsistencies, such as the inefficiency of compatibility and eneration of inaccurate quantities (GONÇALVES, 2020).

2.1.1.3 3D - Modeling

The dimension in question involves the union of graphic and numerical data for the creation of 3D models. It is the most well-known dimension and, perhaps, less complex, but no less important than the others. Based on parametric modeling, it is possible to obtain a project that ensures a realistic rendering regarding the aesthetic and geometric characteristics of the environment (GARIBALDI, 2020).

2.1.1.4 4D – Construction Planning and Control

From the development of the project in 3D - Parametric Modeling, it is possible, in this dimension, that the time factor is analyzed to guarantee a better planning of the work (GARIBALDI, 2020). Based on the information in question, it is possible to determine the execution times of the most diverse service fronts. With the data in hand and properly linked to the graphic project, it is possible to carry out simulations of physical arrangement and changes at the construction site, as well as to forecast critical situations and reduce the risks related to equipment and material transport (GONÇALVES JÚNIOR, 2020). In addition, decision-making becomes considerably more assertive with an analysis of time and deadlines.

2.1.1.5 5D - Budgeting

Based on the aesthetic and geometrical information of the project, as well as the deadline for carrying out the activities, it is possible to obtain greater precision with regard to the costs of the project. Based on the information obtained in this dimension, based on the costs linked to the various items in the project, those responsible for the work are able to have a more detailed view, with regard to the financial aspect of the construction. Thus, greater assertiveness in the execution of budgets is obtained, as well as a more precise and real physical-financial schedule (GONÇALVES JÚNIOR, 2020).

2.1.1.6 6D - Sustainability

The dimension in question is also known as iBIM or Integrated BIM, since it is able to link information regarding the management and operation of the facilities. The data obtained through the 6D BIM include equipment maintenance schedules and the like, the expected useful life of a specific item or with regard to the construction as a whole, information regarding the respective manufacturers, among others. With this, it is possible that decision making is increasingly easier and more accurate, since it allows acting on items with a longer useful life and less need for maintenance, for example.

2.1.1.7 7D – Management and maintenance

The dimension in question directly refers to aspects of management and maintenance of buildings and their various facilities. This dimension is able to control the equipment warranty, data from manufacturers and suppliers, operating costs (DARÓS, 2019) and other essential items so that the management of the enterprise is carried out in an objective and clear manner. Essential information is: type of item; specification; the time of the next maintenance or replacement; the warranty period, among others. This allows an effective maintenance of the building, and, in the case of faults, it will be possible to quickly locate and repair them (CZMOCH and PEKALA, 2014).

2.2 TAILINGS DAM

Tailings dams are usually a lake where by-products from mining or the chemical industry are eliminated (ARAÚJO, 2019). Tailings with different geological and geotechnical characteristics and properties can be found, due to the great diversity of treatment that ores receive and the multiplicity of these materials (KOSSOFF, 2014).

According to Silva (2010), tailings dams differ slightly from conventional dams, in which the main difference is that the former have a more inclined slope upstream. This is because these constructions do not need to withstand a rapid lowering of the reservoir level, which generally occurs in water accumulation dams. However, the design and construction techniques are the same.

2.2.1 Downstream Upgrading Method

The downstream upgrading tailing dam's method was initially developed to reduce the risk of liquefaction caused, mainly, in the upstream high dams. This method can be characterized as more conservative when compared to the others, due to the fact that it is not raised on the tailings already deposited, as is done in the upstream dam. Thus, it is possible to have greater control of soil compaction and percolation, in addition to greater knowledge about the soil that will serve as support for the new elevation.

The downstream upgrading dam is made from a starting dyke and the elevations are implanted downstream until reaching the final level of the project. The system has elevations that are structurally independent of the tailings disposal, and can have all elevations built with the same material. In this method, the dam can be design for great heights, always incorporating an internal drainage and waterproofing system, often made with compacted clay, allowing control of the dam's saturation line and increasing stability (SOARES, 2010).

The main advantage of this method is the stability of the dam, since each rise is independent and contains drainage systems capable of preventing rupture caused by liquefaction, for example. However, because they need larger volumes of material, they present higher costs in the construction processes, in addition to requiring a larger area for the lifting to be carried out (ARAÚJO, 2006).

Another advantage of this method is present in the lifting process where there is the control of the launch and the compression. This means that the internal drainage systems can be installed throughout the construction of the dam and extended during its raising, which allows the control of the saturation line in the dam structure and increases its stability (KLOHN, 1981).

2.2.1.1 Dam monitoring instruments

One of the resources used to classify the safety, over the life of the dam, is instrumentation. According to Fonseca (2003), an instrumentation program tends to provide parameters on the reliability of the readings and the harmony between the relation to the methodologies that were applied and the project premises. Dams have specific conditions due to the existence of points predisposed to problems in the foundation and structural weakness, requiring a well-designed project in the choice of instrumentation for monitoring. According to Machado (2007), the designer needs to understand the physical and mechanical phenomena that the instruments will be subjected to in the field installation and how they will perform in the face of working conditions.

The main data that are monitored by the instruments are piezometry, downstream flow, rainfall, surface topographic landmarks and reservoir water level. The information collected showed the capacity of the dam to absorb, drain and pour, in addition to showing the behavior of water variation in the reservoir and structures.

2.2.1.2 Certification

According to ABNT (2014) certification is the process in which it is assessed whether a given product or service meets the standards. This assessment is based on internal and/or external audits, the production process, sample collection and testing, steps that are specified in specific regulations in force and, when the result of these audits is satisfactory, this certification is granted. Among the main certifications, the international certification ISO (International Organization for Standardization) stands out, that was created in 1946 with the objective of developing and promoting standards that are used in associated countries, about 160 countries currently (INMETRO, 2021). In Brazil, the only representative of ISO is ABNT (*Associação Brasileira de Normas Técnicas*, in english, Brazilian Association of Technical Standards), a private and not-for-profit entity that also assumes national level certifications, NBR (*Norma Técnica Brasileira*, in english, Brazilian Technical Standard).

2.2.2 ISO 14000

ISO 14,000 is a series of standards corresponding to the Environmental Management System (EMS). According to the Ohara (1998), the purpose of that is balance environmental protection and pollution prevention with social and economic needs.

2.2.3 NBR 13028

NBR 13028:2006 was prepared by the Special Study Committee for Project Development for Disposal of Waste and Waste in Mining and, in 2017, it was replaced by NBR 13028: 2017. Named: Mining - Elaboration and presentation of dams project for disposal of tailings, sediment containment and water reservoir - this certification presents the requirements defined as minimum for the elaboration and presentation of the project of a mining dam (ABNT, 2017). The main objective of this certification includes the safety conditions of the dam, its operation and its future decommissioning. Thus, it is possible to contribute to the minimization of impacts on the environment.

3 METHODS AND TECHNIQUES

The methodology used was divided into two stages. The first one was to understand better the theme in which it was worked, through na exploratory bibliographic research about BIM and all the dimensions, the way the dams are built, considering all the stages and also the part of the after-work, that is, the monitoring and also about the existing certification process. For the bibliografic reference, researches were used in Brazil and in the world to seek a better comprehension of the theme.

The second stage in other to supply the deficiency of the Brazilian state, that doesn’t have certificate to guarantee the services provided by geotechnical professionals, this study proposes the expansion of Building Information Modeling certification process for application in tailings dams raised downstream: CUB-e GEO.

3.1 CERTIFICATION MODEL CUB-e

Gosling *et al.* (2020) developed a certification model in BIM in order to classify and attest to the level at which builders and designers operate within the BIM dimensions, thus making the level of reliability of these service providers related to the technology in question available to society.

Five levels of certification were created, being Standard, Silver, Gold, Platinum and Diamond (Figure 2) and the certification is based on the company's fields of activity. The companies that wish to be certified will be submitted to a checklist in which they are analyzed based on pre-established parameters according to the area of operation of the certificate. These are mapped from 0 to 1 among several items that are evaluated together with weights defined by the importance of each item. For the company to be certified in one dimension it is necessary that it reaches a minimum score of 75% and in this way it can be analyzed in the next one so that it acquires the next certification seal (Gostling *et al.*, 2020).

Figure 2 - Image Standard CUB-e seals, Silver, Gold, Platinum and Diamond (left to right)

Source: Gosling *et al.* (2020)

4 CUB-e GEO CERTIFICATION

Initially, the checklist was designed for general application within all areas of civil construction. The BIM certification model proposed by the work aims to certify builders and designers who work in the different dimensions of BIM and areas of application of Architecture, Engineering, Construction and Operation (AECO), such as, for example, project elaboration and/or execution.

This work, however, has the objective of taking the certification specifically for the Geotechnical branch, more specifically for the works of Raised Tailings Dams downstream, showing the benefits of the execution of a work executed with more controlled and planned parameters as it would be the application of BIM in the area and seeking to show companies the advantages of working with BIM and having CUB-e GEO certification. Thus, the company must comply with the minimum requirements imposed to guarantee the seal (Figure 3).

Figure 3 - Image Standard CUB-e GEO

Source: Authorial (2021)

4.1 CHECKLIST

In order to continue the certification, a form was developed to evaluate companies in the geotechnical industry that use BIM in tailings dam works high upstream. The analysis and construction of this checklist was based on the knowledge acquired during the studies on BIM and tailings dams and also on the certifications listed in section 2.3.1 and the standards listed in section 2.3.2.

Weights were assigned to the dimensions based on the relevance of each one for a good executive project of tailings dam raised downstream. For this, 5% of the points went to the 1D dimension, 5% of the points to the 2D dimension, 15% to the 3D dimension, 15% to the 4D dimension, 10% to the 5D dimension, 20% to the 6D dimension and 30% for the 7D dimension. It is important to emphasize that in each dimension the distribution of points was made equally among all the items listed, due to the importance of all the elements present. However, we consider some essential items in 3D, 6D and 7D dimensions that must meet the requirements imposed by the checklist with excellence. Otherwise, grade 0 will be given for the given dimension and the company will fail the certification process.

The first page of the checklist presents the name of the company, business name, national legal entity registration, employee responsible for monitoring the appraiser, contact information and number of employees. In addition, the auditor responsible for this assessment is informed. On the following pages, each BIM dimension is measured and commented on separately. For this, different items were developed and discussed to be evaluated. All of these parameters are evaluated in each company and scores are given for each area of operation.

The first dimension is about the data collected before the work, implantation, and the conception itself (Table 1). Thus, the checklist seeks to analyze in relation to compliance with the laws and protocols imposed by the government and by the people responsible for inspection. So, seeking to root the BIM methodology within Geotechnical companies, more specifically in dams.

Table 1 – CUB-e GEO Form

CUB-e geo	**CUB-e GEO SEAL'S OFFICIAL FORM**	
	Responsible appraiser:	
	Date: XX/XX/XXXX	Page: 2
FIRST DIMENSION	Geotechnical investigations	0,63%
	Laboratory and field tests	0,63%
	Topography - drone georeferencing	0,63%
	Neighborhood precautionary insection	0,63%
	Appropriation plan (if necessary)	0,63%
	Environmental viability	0,63%
	Economic viability	0,63%
	Provisioned documentation not prefecture	0,63%

Source: Authorial (2021)

In the second and third dimensions, it will be analyzed whether the projects were modeled in a consistent, practicable way, with the necessary details and in a way that does not cause ambiguity (Table 2). The parameterization of the projects, the compatibility between them, the composition of the "As Built" and descriptive information about the materials, equipment inserted in the project, the way the team is supervised, the analysis of the projects already completed must be investigated. In the dimension in question, we are considering that the items "Project compatibility" and "Project Details" are extremely important for the creation of projects in BIM and, therefore, your score is necessary so that the dimension is not reset.

Table 2 – CUB-e GEO Form

CUB-e geo	**CUB-e GEO SEAL'S OFFICIAL FORM**	
	Responsible appraiser:	
	Date: XX/XX/XXXX	Page: 2
SECOND DIMENSION	Hardwares support the softwares	0,31%
	Software license	0,31%
	Construction site design	0,31%
	Earthmoving project	0,31%
	Poll report	0,31%
	Excavation and foundation project	0,31%
	Infrastructure project	0,31%
	Drainage project	0,31%
	Descommissioning project	0,31%
	Techinical qualification of the team responsible for the projects	0,31%
	Viability of qualified labor	0,31%
	Project compatibility	0,31%
	Executability of projects	0,31%
	Detalhamento dos projetos	0,31%
	Project coordinator (BIM Manager)	0,31%

	Legal construction guarantees	0,31%
	As Built	0,31%
THIRD DIMENSION	Hardwares support the softwares	0,94%
	Software license	0,94%
	Construction site design	0,94%
	Earthmoving project	0,94%
	Excavation and foundation project	0,94%
	Infrastructure project	0,94%
	Drainage project	0,94%
	Descommissioning project	0,94%
	Techinical qualification of the team responsible for the projects	0,94%
	Viability of qualified labor	0,94%
	Project compatibility	0,94%
	Executability of projects	0,94%
	Detalhamento dos projetos	0,94%
	Project coordinator (BIM Manager)	0,94%
	Legal construction guarantees	0,94%
	As Built	0,94%
	Parameterization	0,94%

Source: Authorial (2021)

In the fourth dimension, regulatory factors will be analyzed so that efficient planning of the work can be done (Table 3). In this step, as previously seen, the time factor is analyzed and, in this way, we can more accurately determine the periods of each service front, in addition to forecasting the inputs, materials and equipment necessary for the completion of each stage. For this, the checklist in question will analyze whether the services listed are being performed in the dam works using BIM.

For a good planning of a dam work downstream, it is essential that there is a macro schedule with a succinct and easy-to-read vision, explaining the main points of the project such as the earthmoving, cutting, embankment and elevation phase and a micro schedule, in which all these stages will be detailed. In this stage, the histograms of labor and equipment will be made with the forecasted quantities throughout the work, so that it is possible to analyze the respective frequencies and, if there is any dispersion, correct it. Also, descriptions of the elements that make up the construction site will be made as well as an analysis of its location.

Table 3 – CUB-e GEO Form

	CUB-e GEO SEAL'S OFFICIAL FORM			
	Responsible appraiser:			
	Date:	XX/XX/XXXX	Page:	3
FOURTH DIMENSION	Executive schecule - Macro			1,36%
	Executive schecule - Micro			1,36%
	Manpower histogram			1,36%
	Analysis of the location and division of the construction site			1,36%

	Histogram of equipment, machinery and tools	1,36%
	Order schedule and delivery of materials on site	1,36%
	Handwares support the softwares	1,36%
	Communication entre softwares	1,36%
	Software license	1,36%
	Schecule adequacy/optimization - replanning	1,36%
	Technical qualification of the team responsible for the schedule	1,36%

Source: Authorial (2021)

In the fifth dimension, the costs of the tailings dam work will be raised and, due to the high index of information on the projects as well as a detailed execution time, this step becomes more effective from an economic point of view (Table 4). This is possible to affirm, since a more efficient quantitative survey is carried out, thus being able to estimate costs more precisely, in addition to having forecast the amount of manpower required for each service in the planning stage. Thus, compositions of unit cost of materials and equipment that will be needed to make this work feasible will be made, in addition to compositions of direct and indirect labor costs. It should be noted that all prices, including the mobilization and demobilization phases, must be budgeted so that a commercial proposal is made as close to the reality as possible.

Table 4 – CUB-e GEO Form

CUB-e geo	CUB-e GEO SEAL'S OFFICIAL FORM	
	Responsible appraiser:	
	Date: XX/XX/XXXX	Page: 4
FIFTH DIMENSION	Financial Valuation - Macro	0,71%
	Financial Valuation - Micro	0,71%
	Hardwares support the softwares	0,71%
	Communication between softwares	0,71%
	Softwares Licenses	0,71%
	Budget Adequacy/Optimization	0,71%
	Technical qualification of the team responsible for the budget	0,71%

Source: Authorial (2021)

The sixth dimension involves the analysis of items related to sustainability (Table 5). Therefore, in order to carry out increasingly sustainable works, it is necessary to take into account some points to be raised at the beginning and during the construction of the project. In principle, all environmental documentation necessary for the execution of the project must be taken into account, which results in licenses specific to the reality of the work. In addition, carrying out the Environmental Risk Management Plan (PGR) is of paramount importance, since qualified professionals are responsible for understanding the risks that the execution of the dam will generate for the environment and the surrounding population, offering and documenting more effective solutions and efficient to treat them.

As a consequence of the analyzes carried out until then and as the construction progresses, it is possible to obtain the classification of each one of the residues, as well as their destination. Any improvement opportunities identified during the work must be carried out and considered in a new revision of the PGR. In addition, all destination movements must be registered so that the work meets inspection standards.

In this dimension, we are considering that meeting the item “Environmental Risk Management” is essential, given the importance of knowing about all possible environmental damages that can occur in a tailings dam work and how to mitigate them. Thus, it must be attended to so that the dimension is not reset.

Table 5– CUB-e GEO Form

CUB-e geo	**CUB-e GEO SEAL’S OFFICIAL FORM**	
	Responsible appraiser:	
	Date: XX/XX/XXXX	Page: 5
SIXTH DIMENSION	Environmental Responsibility	1,55%
	Losses and Tailings	1,55%
	Environmental Licenses	1,55%
	Classification of waste	1,55%
	Disposal of waste	1,55%
	Sustainable Policies - Inputs	1,55%
	Sustainable Policies - Contributors	1,55%
	Sustainable Policies – Customer, Society, Environment	1,55%
	Environmental risk management	1,55%
	Calculation of the useful life of the dam	1,55%
	Maintenance os Structures	1,55%
	Compliance with NBR 13028:2017	1,55%
	Compliance with ISO 14000	1,55%

Source: Authorial (2021)

In the seventh dimension, the management and maintenance factors of the structure are analyzed in order to optimize its life cycle, budgetary and project adjustments, the “As Is”, that is, how is the condition of the structure in terms of its safety and functioning, and assessments of the impacts generated during its use. In this way it is possible to list items that need attention, those that are in compliance and which analyzes should be made after this assessment. The information to be compared will be that obtained in the first dimensions established during the project conception, the “As built” (Table 6).

It is also observed the history of the stability analysis of the slopes, if there are elevations. It should be assessed whether they were executed correctly in accordance with the raising standard, verifying their behavior based on the parameters defined by the tests performed and by reading the existing monitoring instrumentation. In addition, it should be analyzed if the water level does not exceed the maximum defined in the project, if the free edge remains adequate in order to avoid possible overtopping and, mainly, if the structure remains safe after these changes.

The form of these analyzes will be based on SPT tests, field inspection, photographs that prove everything that was observed to be analyzed in comparison with previous documents, with the definition of the current geotechnical parameters of the dam and with the studies made by teams of geotechnics, geology and hydrotechnics. The final results of all these studies will make it possible to define the stability of the dam, its level of safety and whether it is subject to liquefaction or any other hydrogeological phenomenon. It is important to state that the operation of a dam that is subject to the phenomenon of liquefaction is prohibited.

Considering the importance of ensuring safety on the heights of the dam and monitoring it in real time to prevent accidents, these two items were considered essential in this dimension. Thus, they must be attended to so that the dimension is not zeroed and, as a consequence, the company fails the certification.

Table 6 – CUB-e GEO Form

CUB-e geo	**CUB-e GEO SEAL'S OFFICIAL FORM**			
	Responsible appraiser:			
	Date:	XX/XX/XXXX	Page:	6

SEVENTH DIMENSION	Documentation (Permit and Licenses)	1,31%
	Reports and tests	1,31%
	Hardwares support the softwares	1,31%
	Communication between software	1,31%
	Softwares Licenses	1,31%
	Schedule adequacy - Replanning	1,31%
	Adequacy/Optimization of the budget	1,31%
	Life cycle changes and monitoring	1,31%
	Qualification os the team responsible for the schedule	1,31%
	Evaluation of those responsible	1,31%
	Ecological impact assessment	1,31%
	Public health impact assessment	1,31%
	Hydrological impact assessment	1,31%
	Assessment of sedimentological impact	1,31%
	Security impact assessment	1,31%
	Impact assessment of tailings containment	1,31%

	Slope stability assessment	1,31%
	Evaluation of the settlement	1,31%
	Environmental demand assessment	1,31%
	Drainage system assessment	1,31%
	Real-time monitoring	1,31%
	Conference of monitoring instruments	1,31%
	Security / Raising / Stability	1,31%

Source: Authorial (2021)

5 CONCLUSION

Building Information Modeling (BIM) as a technology which aims to integrate all stages of construction, has gained great visibility for all the benefits brought with it. As a result of this, it is visible that the use of the methodology in question has steadily increased and, because of that, studies involving this subject have been growing in the same way.

When two decrees related to BIM were stablished in Brazil, the fact mentioned above was even more present in the daily life of civil construction. The first decree, defined in 2019, establishes precisely the promotion of an adequate environment for the use of BIM, creating good conditions for the investment in the whole country (BRASIL 2019). The second decree stablished in 2020, stipulated that the technology in question is implanted directly or indirectly in the works and engineering services carried out by public agencies and entities of the federal public administration (BRASIL, 2020). So, it is noted that the increase in research and improvements in this theme have justifications that goes beyond the useful, starting to involve federal laws. Given the above, it is visible that BIM can be extremely useful when used in a correct and standardized manner. In addition, it is possible that it will assist in the less technological sectors of civil construction, such as geotechnics.

The aforementioned area presents a certain delay when it comes to technological improvements. Based on recent events in Brazil, one of the most exposed types of construction involving geotechnics, was the tailings dams, since the collapse of many caused great losses to some regions of the state of Minas Gerais. Therefore, another measure was introduced in Brazil. Law number 14,066, of September 30, 2020, defines the prohibition of the construction or raising of mining dams by the upstream method, a method that, because it has its own tailings as a basis, puts its stability at risk.

That said and considering that the federal authorities have taken appropriate action, it is necessary that the technology to be used in the construction of dams is being constantly improved. In addition, the use of checklists at different times of the construction in question is beneficial, is able to avoid numerous errors and, possibly, brings great advantages such as the extension of the dam's useful life. In addition, by completing the checklist formulated to standardize and obtain more details on the monitoring of the construction, it was important to create a certification that ensures that the services performed in the dam project are being faithfully monitored, monitored and performed the necessary know-how. For this purpose and, linking the fact that there are no BIM certifications for dam projects, the CUB-e GEO was created, through the existing CUB-e certification by Gosling *et al.* (2020).

From the percentages previously determined to achieve CUB-e GEO certification, it is possible to distinguish companies whose services fall under the requirements contained in the dam construction check list. The aspects analyzed consider everything from the location of the construction, in view of topography, drainage and the like, up to the maintenance of the dam already executed. In addition, the form in question is divided according to the first seven BIM dimensions, in order to deliver a more accurate and complete result, analyzing the project execution process through the interoperability that the methodology offers. Thus, The BIM technology associated with tailings dams can contributes to safety, improving executive and monitoring processes, reducing the probability of failure associated with a tailing dam.

REFERÊNCIAS

ABNT - ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. Norma Técnica. ABNT NBR 13028:2017: Mineração - Elaboração e apresentação de projeto de barragens para disposição de rejeitos, contenção de sedimentos e preservação de água - Requisitos, [S. l.], 14 nov. 2017. Available in: https://www.abntcatalogo.com.br/norma.aspx?ID=382573. Acess in: apr, 2021.

ARAÚJO, Henrique Antônio de Oliveira. Avaliação da estabilidade das estruturas de desativação de barragens de rejeito. 2019. 94 f. TCC (Graduação) - Curso de Engenharia Civil, Engenharia Civil e Ambiental, Universidade de Brasília, Brasília, 2019.

ARAÚJO, C. B. (2006). Contribuição ao estudo do comportamento de barragens de rejeito de mineração de ferro. Tese de Doutorado, Universidade Federal do Rio de Janeiro, Rio de Janeiro, RJ, Brasil.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. Certificação. In: O que é certificação e como obtê-la? [S. l.], 2014. Available in:<: <http://www.abnt.org.br/certificacao/o-que-e>. Acess in: fev, 2021.

BRASIL. Decreto n° 9.983 de 22 de Agosto de 2019. Aprova a Estratégia Nacional de Disseminação do Building Information Modelling e institui o Comitê Gestor da Estratégia do Building Information Modelling. Available in < http://www.planalto.gov.br/ccivil_03/_ato2019-2022/2019/decreto/D9983.htm > Acess in: nov, 2020.

BRASIL. Decreto n°10.306, DE 2 DE ABRIL DE 2020. APROVA A a utilização do Building Information Modelling na execução direta ou indireta de obras e serviços de engenharia realizada pelos órgãos e pelas entidades da administração pública federal, no âmbito da Estratégia Nacional de Disseminação do Building Information Modelling- EstratégiaBIMBR, instituída pelo Decreto nº 9.983, de 22 de agosto de 2019.. Available in < https://www.in.gov.br/en/web/dou/-/decreto-n-10.306-de-2-de-abril-de-2020-251068946 > Acces in: nov, 2020.

CZMOCH, I.; PEKALA, A. Traditional design versus BIM based design. Procedia Engineering, v. 91, p. 210-215, 2014.

DARÓS, José, “Guia completo: BIM 10D construção industrializada”. Available in: <https://utilizandobim.com/blog/bim-10d-construcao-industrializada/>. Acess in: jan, 2021.

EASTMAN, Chuck et al. Manual de BIM: um guia de modelagem da informação da construção para arquitetos, engenheiros, gerentes, construtores e incorporadores. Bookman Editora, 2014.

GARIBALDI, Bárbara Cristina Blank, “3D ao 7D – Entenda todas as dimensões do BIM”. Available in: <https://www.sienge.com.br/blog/dimensoes-do-bim/>. Acess in: nov, 2020.

GOSLING, Janaina Madureira *et al.* Evaluation Process for Building Information Modeling (BIM): CUB-e Certification. Brazilian Journal of Development, v. 6, n. 8, p. 55998-56020, 2020.

KLOHN, E. J. (1981). The development of current tailing dam design and construction methods. In: WILSON, D. (Ed.) Design and construction of tailing dams. Golden: Colorado School of Mines.

KOSSOFF, D., Dubbin, W. E., Alfredsson, M., Edwards, S. J., Macklin, M. G., & Hudson-Edwards, K. A. (2014). Mine tailings dams: characteristics, failure, environmental impacts, and remediation. Applied Geochemistry, 51, 229-245.

MACHADO, William Gladstone de Freitas. Monitoramento de barragens de contenção de rejeitos da mineração. 2007. Dissertação (Mestrado - Engenharia Mineral) - Escola Politécnica da Universidade de São Paulo, [S. l.], 2007. Available in: <https://www.teses.usp.br/teses/disponiveis/3/3134/tde-31032008-154124/publico/DissertacaoWillianGladstoneMachado.pdf>. Acess in: set, 2020.

MINISTÉRIO DA ECONOMIA (Brasil). INMETRO. O que é ISO? [S. l.]. Available in: <http://www.inmetro.gov.br/qualidade/responsabilidade_social/o-que-iso.asp>. Acess in: mar, 2021.

OHARA, Luis Fernando; GHIZZI, Maria Luiza Pedroso. Normas ISO 14000: Sistema de Gestão Ambiental. Universidade de São Paulo, 2020. Available in: http://www.qualidade.esalq.usp.br/fase2/iso14000.htm. Acess in: mar, 2021.

SILVA, Washington Pirete. Estudo do potencial de liquefação estática de uma barrage de rejeito alteada para montante aplicando a metodologia de Oslon (2001). Orientador: Prof. Dr. Romero César Gomes. 2010. 113 f. Dissertação (Mestrado em Engenharia Geotécnica) - Universidade Federal de Ouro Preto, Ouro Preto, 2010.

SOARES, Lindolfo. Barragem de Rejeitos: Tratamento de minérios. *In*: BARRAGEM de rejeito: Tratamento de minérios. 5. ed. Rio de Janeiro: Adão B. da Luz, João Alves Sampaio e Silvia Cristina A. França, 2010. v. 1, cap. 19, p. 831–896. ISBN CCL00410010.

FONSECA, Alessandra da Rocha. Auscultação por instrumentação de barragens de terra e enrocamento para geração de energia elétrica - Estudo de caso das barragens da UHE São Simão. 2003. Dissertação (Mestrado em Geotecnia) - Universidade Federal de Ouro Preto, [S. l.], 2003.