Tekhnê

Tecnología al servicio de la sociedad

Universidad Distrital Francisco José de Caldas - Facultad Tecnológica

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• Superior izquierda: Total circuit simulation with input voltage Vin=4Vref/5 (Rendón, A.)
• Superior derecha: General structure of the building (Coral, J., Camacho, C. and Torres, B.)
• Centro: Beams and load types (Coral, J., Camacho, C. and Torres, B.)
• Inferior izquierda: Setting up the operational amplifier to emulate the behavior of the LM324 (Rendón, A.)
• Inferior derecha: Niemeyer's construction methods (Muñoz, V., Martínez, M. and Ortiz, C.)

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Revista Tekhnê

La revista **Tekhnê** es una publicación institucional de la Facultad Tecnológica de la Universidad Distrital Francisco José de Caldas. Posee un carácter científico, y atiende a la comunidad nacional e internacional especialista en áreas de ingenierías eléctrica, electrónica, mecánica, de sistemas, industrial y civil. Publica resultados de investigación en inglés (artículos originales e inéditos), y está completamente abierta a especialistas de todo el mundo en calidad de autores y/o lectores. Es arbitrada mediante un proceso doble ciego, con rotación continua de árbitros. La periodicidad de la conformación de sus comités Científico y Editorial está sujeta a la publicación de artículos en revistas indexadas internacionalmente por parte de sus respectivos miembros.

Periodicidad

La revista **Tekhnê** posee una periodicidad semestral, coincidente con los semestres académicos de la Universidad Distrital. La publicación se realiza los meses de julio y diciembre. El primer volumen de la revista se publicó el primer semestre de 2003, manteniendo su regularidad hasta la fecha.

Misión

La revista **Tekhnê** tiene como misión divulgar resultados de investigación realizados en el área de la ingeniería, a través de la publicación de artículos originales e inéditos, realizados por académicos y profesionales pertenecientes a instituciones nacionales o extranjeras del orden público o privado. Propende por la difusión de resultados y su acceso abierto y libre.

Público objetivo

La revista está dirigida a docentes, investigadores, estudiantes y profesionales interesados en la actualización permanente de sus conocimientos y el seguimiento de los procesos de investigación científica en el campo de la ingeniería.

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Back cover picture:
- Top left: Total circuit simulation with input voltage Vin=4Vref/5 (Rendón, A.)
- Top right: General structure of the building (Coral, J., Camacho, C. and Torres, B.)
- Middle: Beams and load types (Coral, J., Camacho, C. and Torres, B.)
- Lower left: Setting up the operational amplifier to emulate the behavior of the LM324 (Rendón, A.)
- Lower right: Niemeyer's construction methods (Muñoz, V., Martínez, M. and Ortiz, C.)

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Tekhnê Journal

Tekhnê journal is an institutional publication of the Facultad Tecnológica of the Universidad Distrital Francisco José de Caldas (Bogotá D.C. - Colombia). It has a scientific character and serves the national and international community specialized in the areas of electrical, electronic, mechanical, systems, industrial and civil engineering. It publishes research results in English (original and unpublished articles), and is completely open to specialists from around the world as authors and/or readers. It is arbitrated through a double-blind process, with continuous rotation of arbitrators. The periodicity of the formation of its Scientific and Editorial Committees is subject to the publication of articles in internationally indexed journals by their respective members.

Periodicity

Tekhnê journal is published every six months, coinciding with the academic semesters of the Universidad Distrital. It is published in July and December. The first volume of the journal was published in the first semester of 2003, maintaining its regularity to date.

Mission

The mission of **Tekhnê** journal is to disseminate research results conducted in the area of engineering, through the publication of original and unpublished articles by academics and professionals belonging to national or foreign institutions of public or private order. It aims at the diffusion of results and their open and free access.

Target audience

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Declaración de ética y buenas prácticas

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Revista Tekhnê
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Facultad Tecnológica

El comité editorial de la revista **Tekhnê** está comprometido con altos estándares de ética y buenas prácticas en la difusión y transferencia del conocimiento, para garantizar el rigor y la calidad científica. Es por ello que ha adoptado como referencia el Código de Conducta que, para editores de revistas científicas, ha establecido el Comité de Ética de Publicaciones (COPE: Committee on Publication Ethics) dentro de los cuales se destaca:

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• Velar por la libertad de expresión.
• Mantener la integridad académica de su contenido.
• Impedir que intereses comerciales comprometan los criterios intelectuales.
• Publicar correcciones, aclaraciones, retractaciones y disculpas cuando sea necesario.

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La revista incluye una descripción de los procesos seguidos en la evaluación por pares de cada trabajo recibido. Cuenta con una guía de autores en la que se presenta esta información. Dicha guía se actualiza regularmente y contiene un vínculo a la presente declaración ética. Se reconoce el derecho de los autores a apelar las decisiones editoriales.

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Code of ethics and good practice

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Tekhnê Journal
Universidad Distrital Francisco José de Caldas
Facultad Tecnológica

The editorial board of **Tekhnê** journal is committed to ethics high standards and good practice for knowledge dissemination and transfer, in order to ensure rigour and scientific quality. That is why it has taken as reference the Code of Conduct, which has been established by the Committee on Publication Ethics (COPE) for scientific journal editors; outlining the following:

General duties and responsibilities of the editorial board

As most responsible for the journal, **Tekhnê** committee and the editorial board are committed to:

• Joining efforts to meet the readers and authors needs.
• Tending to the continuous improvement of the Journal.
• Ensuring quality of published material.
• Ensuring freedom of expression.
• Maintaining the academic integrity of their content.
• Prevent commercial interests compromise intellectual standards.
• Post corrections, clarifications, retractions and apologies when necessary.

Relations with readers

Readers will be informed about who has funded the research and their role in the research.

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Tekhnê is committed to ensuring the quality of published material, informing the goals and standards of the journal. The decisions of publishers to accept or reject a paper for publication are based solely on the relevance of the work, originality and pertinence of the study with journal editorial line.

The journal includes a description of the process for peer evaluation of each received work, and has an authors guide with this information. The guide is regularly updated and contains a link to this code of ethics. The journal recognizes the right of authors to appeal editorial decisions.

Publishers will not change their decision in accepting or rejecting articles, unless extraordinary circumstances or irregularities are detected. Any change in the editorial board members will not affect decisions already made, except for unusual cases where serious circumstances converge.

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Tekhnê makes available to reviewers a guide to what is expected from them. Reviewers identity is protected at all times, ensuring anonymity.

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Tekhnê is committed to respond quickly to complaints and ensure that dissatisfied claimant can process all complaints. In any case, if applicants fail to satisfy their claims, the journal considers that they have the right to raise their protests to other instances.

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Tekhnê will establish the necessary mechanisms to avoid or resolve potential conflicts of interest between authors, reviewers and/or the editorial board itself.

Complaints/allegations

Any author, reader, reviewer or editor may refer their complaints to the competent authorities.

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Articles

Editorial

Como ya estamos acostumbrados en Colombia, Colciencias realiza cada par de años su proceso de reconocimiento y medición de grupos de investigación a nivel nacional, el cual en las últimas versiones también ha reconocido y categorizado a los investigadores adscritos al Sistema Nacional de Ciencia, Tecnología (SNCTel). A comienzos de septiembre se conocieron los resultados preliminares de esta convocatoria que inició en noviembre de 2018. Luego de su discusión y corrección de acuerdo a las solicitudes de la comunidad académica y científica, los resultados finales fueron publicados el 6 de diciembre de este año.

Para la Universidad Distrital estos resultados muestran un crecimiento y fortalecimiento continuo de su eje investigativo, en gran parte gracias al financiamiento producto del impuesto de estampilla, y por otro lado las nuevas políticas impulsadas por el Centro de Investigaciones y Desarrollo Científico (CIDC). Este crecimiento se ve reflejado en un aumento en grupos de investigación categorizados como A1, pasando de 12 a 17 en esta última medición (por aumento de categoría de grupos A, B y C). También aumentaron los grupos categoría A (se mantuvo la cantidad en 23, lo que implica que grupos A que subieron a A1 fueron reemplazados por otros de categorías inferiores), y los grupos categoría B que pasaron de 16 a 24. En la distribución sobresalen la cantidad de grupos categorizados en la Facultad de Ciencias y Educación, y en la Facultad de Ingeniería. También es notable el incremento en docentes categorizados como Eméritos e investigadores Senior.

Según cifras del CIDC, este incremento en investigación también se ha reflejado en los estudiantes, ya que el número de semilleros de investigación aumentó en los dos últimos años (la misma ventana utilizada por Colciencias) de 238 a 271. En la Facultad Tecnológica tiene una particular apuesta con la ampliación de su sede, espacios que proyectan 55 laboratorios, salas especializadas de investigación y biblioteca.

Ph.D Prof. Fredy H. Martínez S.
Docente Facultad Tecnológica
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Editorial

As we are used to in Colombia, Colciencias carries out every couple of years its process of recognition and measurement of research groups at a national level, which in the last versions has also recognized and categorized the researchers attached to the National System of Science, Technology (SNCTel). At the beginning of September, the preliminary results of this call, which began in November 2018, were known. After their discussion and correction according to the requests of the academic and scientific community, the final results were published on December 6 of this year.

For the Universidad Distrital, these results show continuous growth and strengthening of its research axis, in great part thanks to the financing product of the stamp tax, and on the other hand, the new policies impelled by the Center of Research and Scientific Development (CIDC). This growth is reflected in an increase in research groups categorized as A1, from 12 to 17 in the latter measure (due to an increase in the category of groups A, B, and C). There was also an increase in category A groups (the number remained at 23, meaning that groups A that moved up to A1 were replaced by others in lower categories), and category B groups went from 16 to 24. The number of groups categorized in the Faculty of Science and Education and the Faculty of Engineering stand out in the distribution. Also notable is the increase in professors categorized as Emeritus and Senior Researchers.

According to CIDC data, this increase in research has also been reflected in the students, since the number of research seedlings has increased in the last two years (the same window used by Colciencias) from 238 to 271. In the Technological Faculty, it has a particular commitment with the expansion of its headquarters, spaces that project 55 laboratories, specialized research rooms, and a library.

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Nanotechnology in the construction industry

Nanotecnología en la industria de la construcción

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One of the main characteristics of our century has been the extensive development of science and technology. The discovery of the smallest and the incredibly majestic has allowed us to define the postulates that govern our science, allowing us to understand our environment. It is in this universe of the incredibly small that man has found answers to many of the problems posed by his survival. New technologies have changed the conception of the probable future that affects all areas of knowledge, including Civil Engineering. The technologies that affect this discipline are closely linked to the mastery of matter, and allow the achievement of more efficient and effective tools and materials to develop the work of Civil Engineering.

Keywords: Civil engineering, nanoparticles, nanostructure, nanotechnology, quarts, science

Una de las principales características de nuestro siglo ha sido el amplio desarrollo de la ciencia y la tecnología. El descubrimiento de lo más pequeño y lo increíblemente majestuoso, ha permitido definir los postulados que rigen nuestra ciencia, permitiéndonos comprender nuestro entorno. Es en este universo de lo increíblemente pequeño donde el hombre ha encontrado respuestas para muchos de los problemas que le plantea su supervivencia. Las nuevas tecnologías han cambiado la concepción del futuro probable que afecta todas las áreas del conocimiento, incluida la Ingeniería Civil. Las tecnologías que afectan esta disciplina están muy ligadas al dominio de la materia, y permiten la consecución de herramientas y la obtención de materiales más eficientes y eficaces para desarrollar la labor de Ingeniero civil.

Palabras clave: Ciencia, ingeniería civil, nanoestructura, nanopartículas, nanotecnología, quarts

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Introduction

Nanotechnology encompasses those knowledge and techniques that humans are developing to observe, characterize, understand, predict, and use the properties of nanometric-sized structures (Becerra et al., 2019; Garcia, Osuna, & Martinez, 2018; Ye, Zuo, & Fan, 2018). A nanometer (1 nm) is one-billionth of a meter, a really small length in which we could only align a few atoms. This new discipline has the nanoscale (or nano-world) as its setting, which can be defined as the range of lengths between approximately 1 and 100 nm.

The nano-world is populated by nanostructures and nano-objects that manifest interesting phenomena, which would not appear in them if their size were much larger (Gordillo & Martinez, 2018; Mobasser & Akbar, 2016). It is easy to understand how as a structure becomes smaller the relative fraction of atoms located on its surface increases, giving it different properties (Ali, Negin, & Xie, 2016; Contreras, Rodriguez, & Taha-Tijerina, 2017). Besides, we have to take into account other phenomena that only the intriguing Quantum Mechanics can explain. By controlling the geometry and size of the nanostructures and nanospheres, it is possible to modify the electrical conductivity, coloring, chemical reactivity, elasticity, etc., of many materials (Serena, 2012).

Precursors of the application of nanotechnology

In the field of modern physics, two personalities have distinguished themselves by offering the vision of the future that currently governs the conditions and objectives of materials research. One is the physicist Richard P. Feynman, the other is the theoretical physicist Freeman J. Dyson. Both have made important contributions to the body of knowledge of mankind. For example, Feynman won the Nobel Prize in Physics in 1965 for his research in quantum electrodynamics that contributed to the understanding of elementary particles within the field of high-energy physics. On the other hand, Dyson published in 1979 his renowned theory that deals with the deterioration of ordinary matter in a universe whose main characteristic was a continuous and permanent expansion. However, in the field at hand, the creation of new and incredible materials, both showed at the time a visionary conception of the future.

On December 29, 1959, Richard P. Feynman presented a paper at the annual meeting of the American Physical Society at the California Institute of Technology (Caltech), where he worked as a researcher. The full text of the lecture was intended to explain the problems and advantages of manipulating and controlling objects in nature at microscopic scales. First, he talked about writing all the pages of the famous Encyclopedia Brittanica with atoms on the head of a pin. He pointed out the need for the existing microscopes of that time to be improved to observe objects with 100 times greater magnification. He compared the information stored in a DNA helix with the incipient information handled by the computers of his time, raising the need and the possibilities of electronic miniaturization. He talked about industrial processes of solid evaporation to generate new types of materials. He mentioned the consideration of building atom by atom microscopic machinery to fulfill predetermined functions. The most important aspect of his presentation was the affirmation that as long as human beings had control over the arrangement of molecules and their atoms, new materials with properties unimaginable at that time could be created. In the end, he instituted two awards, still in force, with a permanent fund financed by himself, to recognize any attempt at miniaturization on the scales he had proposed.

On May 16, 1972, Freeman J. Dyson was invited to give a lecture in honor of the writer J. D. Bernal3 at Birbeck College, London, when he was a researcher at the Institute of Advanced Studies in Princeton, New Jersey. In this lecture, he praised Bernal's vision and compared him with Verne regarding many technological developments that have taken place in the present century. However, the essence of his lecture was to discuss the three possible paths that emerging biological technology could take in the future, according to his point of view. The first path he mentioned was the feasibility of what he called genetic surgery, a procedure by which biologists would be able to modify, graft, or remove DNA sequences from living beings to recompose or alleviate their physical structure. The second way was called biological engineering, and it consisted of using genetically redesigned living microorganisms to extract minerals and produce materials through the process of common fermentation. The third and last path he exposed was the self-reproducing machinery, which consisted of imitating the function and reproduction of a living organism with non-living materials on any scale.

Both Feynman and Dyson, for their creative contributions and concepts based on totally scientific facts and knowledge, are currently considered the fathers of so-called nanotechnology. This term refers to a wide range of novel technologies in which materials and objects are manufactured with dimensions between a micrometer and a manometer of length or diameter. Their early joint vision of the future of molecular and biological technology opened up overflowing hopes in the world's scientific communities, regarding the future transformation of industry, materials research, the conservation of terrestrial ecology, the development of cybernetics and space exploration (Ocampo, 1998).

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Some nanomaterials in construction

The nano-concrete

Traditional concrete can be converted into a Nano-Concrete by the following procedures: addition of nanoparticles to the cement, reduction of the cement particles to cement-nanopowder, hybridization of the hydrated calcium silicate (C-S-H), or the incorporation of nano-reinforcements such as nanotubes or nanofibers.

Addition of nanoparticles

There are several nanoparticles, but the most common are Nano Silica (n.SiO2), Nano Titanium Oxide (n.TiO2), Nano Ferric Oxide (n.Fe2O3), Nano Aluminum Oxide (Alumina) (n.Al2O3), and the Nano Clay particles.

The addition of Nanoparticles to the cement has a very remarkable influence on its hydration process, at all scales: nano, micro, and macro, of the chemical compounds that are generated, modifying their structure; this influence includes the nano and microstructure of the (C-S-H) gel, which have a very remarkable effect on the resistance of the concrete at a macro scale.

The Nanoparticles fill the gaps between the cement grains and between the aggregates and act as active cores that increase the hydration of the cement, due to the great reactivity of its surface; they improve its resistant properties, reduce its porosity and the retraction of the concrete that causes its cracking as well as its possible later degradation.

The addition of Nanoparticles also increases the quantity of (C-S-H) of high density, present in the cement paste and decreases the quantities of calcium hydroxide Ca (OH) 2 and the quantity of (C-S-H) gel of lower density; the presence in the concrete of greater quantities of (C-S-H) gel of very high density, increases the resistance to the dissolution of the calcium carbonate of the concrete matrix.

The manufacture of cementitious nanoproducts (nano binders), composed mainly of finely pulverized mineral products such as flying ashes, silica smoke, metakaolin, nano-silica, with the addition of 20%-30% of finely pulverized portland cement, to fill the gaps between the particles of mineral additives, will provide nano products with greater cementitious power and cementitious materials with properties far superior to those of current cement. These new cementitious nanoproducts will significantly reduce CO2 emissions, produced in the manufacture of portland cement with lower energy consumption; they will also reduce the consumption of traditional raw materials, mainly limestone, and the reduction of portland cement clinker.

Properties of the nano-concrete according to the added particle

SiO_2

Improves workability by adding a superplasticizer. More waterproof concrete. Greater resistance to the dissolution of calcium carbonate. Increase of the resistance to compression up to 26%, at 28 days. Increase of the resistance to flexion. Increase in the speed of setting.

TiO_2

Self-cleaning capability. Capacity to eliminate pollutants in the environment such as NOx, CO2 (Photocatalysis), in facades, road pavements. Accelerates the hydration of the cement at an early age. Increases the resistance to compression, bending, and abrasion.

Fe_2O_3

Auto-detection of the compression stress supported. Real-time control of the tensional state without using sensors. Intelligent structures.

Al_2O_3

Increase of the Modulus of Elasticity up to 140%.

Processed clay

A very important increase of the compression and traction resistance of the cement mortars. More waterproof concrete. Resistance to chlorides. Self-compacting concretes. Reduction of shrinkage. Increase of the resistance, after the first fracture, using exfoliated clay particles covered with a PVA layer.

Reduction of cement particles to cement nanopowder

There are two procedures: High energy comminution of Portland cement clinker (top-down) and chemical synthesis (bottom-up). NanoConcrete has cement particles of size <500 nanometers. Properties of NanoConcrete Among its properties we have: Processed at room temperature, heat resistance (>600^{o}C), reduction of autogenous cracking, a drastic reduction of CO2 in its manufacture, higher initial and final compression and traction resistance, good workability, no need to use superplasticizers, higher resistance to segregation, greater acceleration of hydration, better bonding between the aggregates and the cement paste, increased toughness, and shear, tensile and flexural strength, very good chemical compatibility with carbon nanotubes to make *smart concrete* and greater durability.

C-S-H hybridization

The hybridization process modifies the structure of the hydrated calcium silicate (C-S-H) of the cement by three different processes: inserting organic nanomolecules in the structure of the (C-S-H) gel, inserting *invited nanomolecules* to establish covalent bonds with the structure of the (C-S-H) gel and inserting *invited nanomolecules* in the places of the chain of the (C-S-H) gel, in the points that have defects and in the spaces between layers. Nanotechnology concretes are also manufactured incorporating nanotubes or carbon nanofibers (CNTS, CNFS).

These nanomaterials, due to their extraordinary mechanical properties, also electronic and chemical, can increase the mechanical properties of cementitious materials, such as Young's modulus by the high modulus of carbon nanotubes (1.0 TPa) and tensile strength; in addition, they can give cementitious materials other important properties, such as: serving as a shield for electromagnetic fields and the ability to turn them into *smart* materials The system can perform a self-check, in real time, of its state of cracking, of its tensional state and of its deformation during its useful life. Nanomaterials have the capacity to significantly increase the properties of cementitious materials, due to their high specific surface (up to $600 m^2/g$) and their high slenderness index (>1000), with the potential to practically eliminate the autogenous cracking that occurs in concretes and mortars during the hardening process, distributing the stresses generated by the entire mass of the cementitious matrix.

Nanostructured steel

The tensile strength of traditional steel barely reaches 10% of its theoretical value (27.30 GPa) as a result of defects and impurities in its internal structure, which originated during the manufacturing process.

At present, the so-called Nano-Structured Steel is already being manufactured, using a new manufacturing technology that manipulates, at a nano-scale, its structure during the complex manufacturing process.

The new manufacturing technology achieves a reduction in size and a greater uniformity of the microcrystals that are formed, eliminating or reducing the defects in the crystals (size 100-200 nm) If there is any microcrack or discontinuity during manufacture, it will be very thin in width and very small in length, covering a smaller area within the mass of steel. The modification of the microstructure is produced by the addition of self-assembling nanoparticles (e.g., copper nanoparticles) on the edges of the steel grains. Another technique for modifying the structure of the steel to make it more compact, uniform, and practically defect-free, is to subject the steel to a process of severe plastic deformation. Some types of nano-structured steel are currently manufactured, such as Microcomposite Multistructural Formable Steel (MMFX), bainitic steel, Advanced high strength steels (AHSS), Nanostructured ODS ferritic steel (European project), martensitic steel, and High Resistance, low carbon steel for building construction, which incorporates nanoparticles of copper (Cornejo, 2015).

Nanotechnology in the construction industry

Nanotechnology has been implemented in different industrial sectors, although some experts believe that the construction sector has presented a certain lag compared to areas such as electronics, automotive, and pharmaceutical chemistry, in which consolidated and even marketable results have been obtained. This is pointed out by Dr. María José López Tendero, who was coordinator of the Construction Technology Institute (AIDICO), based in the city of Valencia, Spain, and is currently co-founder of Laurentia Technologies (a company specialized in the development and manufacture of nanomaterials), which establishes that the main advances in construction are in the scientific field. The nanoscience of cementitious materials has been studied with greater interest, with an increase in the knowledge and understanding of nanoscale phenomena (for example, the structure and mechanical properties of the hydrated phases of cement, the interfaces in concrete, and the mechanisms of degradation). Progress has also been made in the knowledge at the nanoscale, thanks to the use of techniques such as electronic microscopy, atomic force microscopy, nuclear magnetic resonance, among others. Concrete can be nano-modified through the incorporation of nanomaterials to control the behavior of the materials and add new properties, or through the modification of molecules in the particles of cement, aggregate, and additives to provide new functionalities. Among them are: low electrical resistivity concretes, self-sensing capabilities, self-cleaning capabilities, microcracking self-repair capabilities, corrosion self-control, etc., the expert points out (González, 2014).

Addition of nanoparticles to Portland cement

Characteristics of nanoparticles

Nanosilica (NS). They are nanoparticles (1 - 500 nm) of amorphous SiO_2 that are insoluble in water. Size, size distribution, and specific surface area are parameters that are defined according to the synthesis process (Björnström, Martinelli, Matic, Börjesson, & Panas, 2004). Thanks to its properties, nano-silica has become the most reactive silica material, so it has been added to materials such as polymers to increase their mechanical strength, flexibility, and resistance to aging (Tobón, Restrepo, & Payá, 2007).

Researchers looking for maximum reactivity used in their NS commercial projects of low crystallinity as shown by

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XRD (Fig. 1), with purities equal to or greater than 99.9%, specific surface area between 160±20 m^2/g and 640±50 m^2/g, density around 0.15 g/cm^3 and average diameter of particles between 5 nm and 20 nm. The addition percentages were generally between 1% and 12% by weight, 1%, 2%, 3%, 5%, 6%, 10% and 12% were used, worked with constant water/cement (a/c) ratio and used commercial superplasticizers (Tobón et al., 2007). Among the few who deviated from this scheme are (Shih, Chang, & Hsiao, 2006) who added percentages of nano-silica below 1% (0.2%, 0.4%, 0.6%, and 0.8%), varied the a/c ratio (0.25, 0.35, 0.45, 0.55 and 0.65) and did not use superplasticizers and (Byung-Wan, Chang-Hyun, Ghi-ho, & Jong-Bin, 2007) who used thicker NS (40 nm and 60 m^2/g) in their project (Kalinski & Hippley, 2005).

Others. In (H. Li, Zhang, & Ou, 2006) they used commercially α nano alumina, greater than 99.99% purity, particles below 150 nm, specific surface of 10±5 m^2/g, and density between 0.3 and 0.5 g/cm^3. It used 3%, 5% and 7% substitution. With constant a/c of 0.4 and cement/sand 1:1. (H. Li et al., 2004) used commercial nanometric iron particles of 30 nm. In percentages of 3%, 5% and 10% by weight. (H. Li et al., 2006) used commercial low-crystallinity nano-titanium (anatase) of 99.7% purity, specific surface 240±50 m^2/g, density between 0.04 and 0.06 g/cm^3, and an average diameter of 15 nm. In percentages of 1%, 3% and 5% by weight (Knofel, 1979).

Incidents in physical properties

(Qing, Zenan, Deyu, & Rongshen, 2007) found that by increasing the percentage of the addition of NS the consistency of the paste decreased slightly and that the opposite occurs with the addition of SF, i.e., NS accelerates the hydration process compared to SF. This is supported by authors like (Björnström et al., 2004) and (H. Li et al., 2004) who found that silica in nanometric sizes accelerates the hydration process and the formation of tobermorite (C-H-S) thanks to its high surface energy (Ganjian & Pouya, 2005).

(H. Li et al., 2004), through microstructural analysis, determined that the samples with higher resistance present denser and more compact textures because the nanoparticles filled the pores (H. Li et al., 2004).

Something similar was found by (Wen-Yih, Jong-Shin, & Chi-Hsien, 2006) when they used organomodified montmorillonites and verified that the permeability was reduced by up to 100 times. It should be highlighted that montmorillonites are microparticles and not nanoparticles, so they can only penetrate up to 0.1 μm pores. This is physically demonstrated in the work of (Ji, 2005) who compares the penetration of water in a normal concrete against one added with NS and finds that in the latter the penetration is significantly lower 146 mm and 81 mm respectively (G. Li, Wang, & Zhao, 2005).

Impact on mechanical properties

Most researchers accept that by increasing the nano-SiO_2 content in portland cement, a substantial improvement in the development of compressive strength is obtained, especially at an early age (3 days). When this behavior is compared with the one presented with the addition of silica smoke, it is noticed that the NS is much more reactive, that is to say, they have more pozzolanic activity (Byung-Wan et al., 2007; H. Li et al., 2004; Qing et al., 2007; Shih et al., 2006).

Impact on mineralogy

In general, the different authors have found that increasing the addition of NS reduces the number, degree of crystallinity, and size of portlandite crystals (Björnström et al., 2004; Byung-Wan et al., 2007; Ji, 2005; H. Li et al., 2004; Qing et al., 2007). They also state that the pozzolanic activity of nano-SiO_2 is higher than that of silica fume, this is irrefutable knowing that pozzolanic activity depends on the composition (silica is the most indicated compound because of its chemical affinity with calcium and its possibility of forming calcium silicates - NS is generally of higher purity than SF), low crystallinity, and specific surface (where NS is much higher). Therefore, the NS can react with the CH crystals formed in ITZ and produce C-H-S, that is, a more stable structure. Thus, the number and size of CH crystals are significantly reduced and the resistance at early ages is increased (McCarthy & Dhir, 2005).

Percentage of addition

In the case of the NS, it can be stated that there is no consensus on what is the most appropriate percentage of addition. Some authors propose that low percentages of addition are better, such as (Shih et al., 2006) who propose 0.6% as the optimum percentage of the addition of NS, to achieve maximum resistance to compression, (H. Li et al., 2006) who found the best results of resistance to bending and compression with 1% of the addition of NS and NT and (Qing et al., 2007) who say that 3% is sufficient to achieve good assimilation of HC. On the other hand, some recommend higher percentages such as (Byung-Wan et al., 2007) and (H. Li et al., 2004) who find significant improvements with additions close to 10% of NS (Mostafa & Brown, 2005).

The nano-trend

Nanotendence in the construction industry can be defined as the trend to use processes to improve material characteristics through the use of nanotechnology.

The best-known process of the nano-trend in the improvement of construction materials is tempered glass that thanks to the implementation of nanotechnology improves its resistance to fracture.

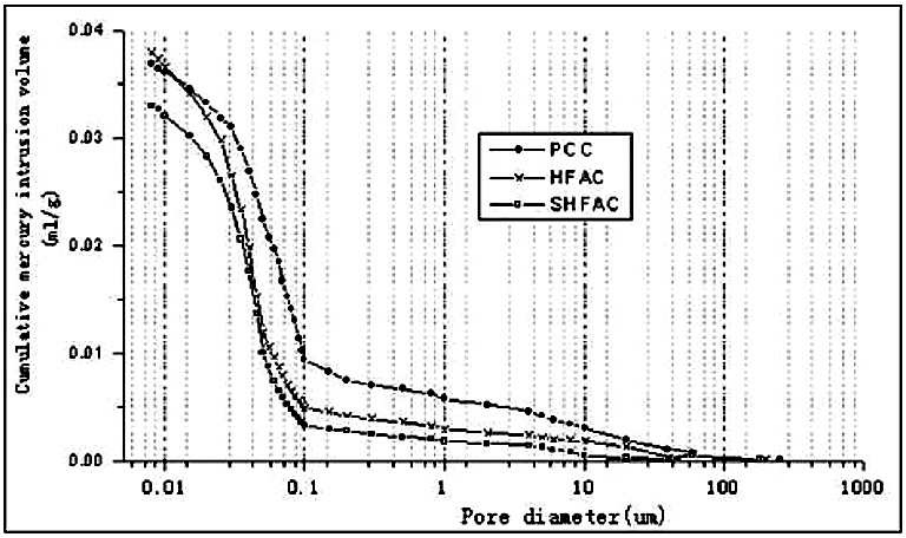

Figure 1. Porosity measurement at 2 year. PCC concrete of Pórtland cement; HFAC concrete with high volumen fly ash (50%); SHFAC concrete with high volumen fly ash (50%) blended with nanosilice (4%) (H. Li, Xiao, & Ou, 2004).

Correctly applied, the nanotendence can improve many materials, from the dispersion of particles in cement to reduce the percentage of water contained in it, improving its strength, to helping materials such as wood with great affinity to absorb and retain water, modifying certain aspects until it becomes hydrophobic, making it repellent.

The benefits that nanotendence can present in the industry can be presented in different ways depending on the point of view that needs to be analyzed. In the structural point of view, we can find that the use of nanotechnology is optimal and recommended, the use of materials with implemented nanotechnology produces less waste thus helping cities and industries by reducing pollution, nanotechnology implemented in the field of construction industry offers practical solutions in the short, medium and long term (Calleja, 2001).

In addition to its great advantages over materials of the same nature exempt from these technologies improvements such as increased durability, strength, hardness, waterproofing, etc.

From an innovative point of view, we have the great technological advance that is implemented today thanks to nanotechnology reaching fields previously unexplored in the industry, and the feedback that can be presented thanks to the possibility of combination in building materials with nanotechnology innovations that can promote new techniques, materials, processes, and styles in construction (Collepardi et al., 2005).

Conclusions

Today it is possible to find many materials that are used in construction to which currently in its development is applied nanotechnology such as:

- The concrete.
- Cement paste.
- Paints and varnishes.
- Carbon nanotubes.
- Ceramics.

In short, it can be concluded that the implementation of nanotechnology in the field of the construction industry, civil engineering, and architecture has brought innovation in the process of doing things in certain ways giving us more and better options to choose when we want to undertake a project.

Despite this, the use of nanotechnologies in construction has certain risks at the time of its use, it is the contamination that can be presented in different areas of nanotechnology and nanosciences, this when the nanoparticles in the air make contact with living organisms, where such cases could cause damage to health and the environment, Despite the few studies that have been carried out in this field, given its relative proximity to the present, the harmful effects on health and the environment have already been identified. Among the major sources of pollution are ash produced in combustion processes, metals in mining and construction, batteries and cells in the energy industry, and unusable batteries in the automotive industry.

It can also be stated, considering the advances that have been achieved thanks to the nano-trend, its benefits, and risks that can be found in its use, that the implementation of nanotechnologies should be sought in other aspects within civil engineering to achieve more advances, realizing

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that the implementation of this brings more positive than negative aspects in the construction industry, thus giving way to nanotechnology to improve processes and innovate the methods and forms that are used today in the industry.

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The architectural influence of Óscar Niemeyer

La influencia arquitectónica de Óscar Niemeyer

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Óscar Ribeiro de Almeida Niemeyer was a great Brazilian architect with a peculiar style in his works. For him, architecture had to become a great work of art capable of touching people on an emotional level. Oscar Niemeyer is recognized for breaking the schemes that were held in architecture. Each of his works is governed by his feelings and way of understanding the world. His work places him as one of the best architects both professionally and personally. He left a legacy in the utilization of light and the use of external and internal spaces, as well as in the construction of flexible and usable materials. Niemeyer caused a global transformation that is not limited to the architectural sector, but also the political and social.

Keywords: Architecture, construction, design, modernism, Niemeyer

Óscar Ribeiro de Almeida Niemeyer fue un gran arquitecto brasileño con un estilo peculiar en sus obras. Para él la arquitectura debía convertirse en una gran obra de arte capaz de tocar a las personas a nivel emocional. Óscar Niemeyer es reconocido por romper los esquemas que se tenían en la arquitectura. Cada una de sus obras se rigen por sus sentimientos y forma de entender el mundo. Su trabajo lo ubica como uno de los mejores arquitectos tanto a nivel profesional como personal. Dejó un legado en el uso de la luz y aprovechamientos de espacios externos e internos, así como en construcción de materiales flexibles y aprovechables. Niemeyer causo una transformación global que no se limita al sector arquitectónico, sino también al político y social.

Palabras clave: Arquitectura, construcción, diseño, modernismo, Niemeyer

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Introduction

The following text will cover a topic that for many people in their thinking may be useless, but for anyone who can see the construction beyond a simple set of walls or a union of materials to create a structure can be a very substantial and necessary text. What leads us to discuss the following topic is the need to show the world the vision of a man who dedicated his entire life to architecture, and that today is a symbol and synonym of the same that taught the world the exquisite art that has every building built with the fundamental bases of aesthetics. This to exalt Oscar Niemeyer as a unique reference in the history of architecture that laid the foundations for all architects of modern times (Philippou, 2013).

Throughout different texts and interviews, Niemeyer talked about his life, and how he went through the process to become the icon of architecture that he is today. He also details his most difficult moments when he was relegated from his nation because he was believed to be an unprepared architect, or when he had to flee because the monarchy took over Brazil, and he being a communist had no place in his city. Different media and more have shown the different stages of Niemeyer's life because he became an icon with his architecture (Read, 2005).

At the age of 20, Niemeyer joined the Socorro Velmelho, which defined itself as a group of the Brazilian communist party (Barros, Costa, & Navarro, 2012; Stierli, 2013). In 1929 he decided to enroll in the national school of fine arts located in the city of Rio de Janeiro, where through the years he learned to finally start his working life in 1932 and culminating in 1934 with graduation and subsequent departure as a professional. Over the years, more specifically 1967, Oscar went into exile in France due to the multiple military dictatorships that occurred at that time. Even so, in France, he did a certain amount of work that led him to earn a special French license that allowed him to create works in the country. He then dedicated himself to the creation of a special work that was directed to the people of the French communist party. After returning to his native country, around 1980, he created multiple works, winning the Pritzker Architecture Prize in 1988. Later, in 1991, he created the Museum of Contemporary Art located in the city of Rio de Janeiro, as well as the Latin American Parliament, and in 2002 he created his museum named Oscar Niemeyer Museum (MON) (Godoi et al., 2013).

Already leaving a little of his life and general works, aesthetics touch here a point of great importance to understand why the works of Niemeyer played a different role in the architectural vision, starting with the definition of aesthetics (Lahoud, 2013). The beautiful or what is perceived as beautiful is an artistic concept connected to everything we think and feel, something that should not be altered by moral reasons or knowledge that society has created in each inhabitant. Beauty is a fundamental characteristic with meaning in each person since it is special meaninglessness in the sight of each person, something incapable of being appreciated if its function or purpose is sought. The simple fact of creating uncertainty makes them monumental and unique, taking this into account the aesthetics were important for Niemeyer since he was in charge of capturing these characteristics in his works, adding all those things that for him meant the pure beauty that he transmitted in his curved strokes. With this term, he thought of giving an idea that would create multiple points of view, both objective and subjective, that could change depending on the context that the aesthetics had created in those who saw it, whether it was one that focused on the beauty of the world that changes with it or one where advertising and all aspects of sales and trends had delivered.

How this article is developed is by thoroughly investigating different texts that talk about Niemeyer's definition of aesthetics. In this way, we intend to reach a hypothesis of the main question of our research: What was aesthetics for Niemeyer's point of view? Different interviews and phrases will lead us to the conclusion of what was his definition of aesthetics. These texts will be studied to know which ones are the most suitable to answer our question since many texts talk about Oscar Niemeyer, but telling about his works and his personal life, which is not the fundamental of our search. It can even be said that there are few texts in which Niemeyer expresses or tells what is his definition and importance of aesthetics in construction. All this will also be complemented with data from his personal life, such as the influence he received from Le Corbusier, or the support of his friend Lucio Costa, because for many Niemeyer's talents for buildings was something that simply emerged from his studies, but few know him behind all this, and even less about the people who were behind the birth of a genius (Bullaro, 2014; Segawa, 1997).

Modernist ideas of a great thinker

Oscar Ribeiro de Almeida Niemeyer Soares Filho is also known as Oscar Niemeyer, was born on December 15, 1907, in Rio de Janeiro; he was a great Brazilian architect. He said that architecture should become a work of art that creates emotions, he did not like straight lines, he was attracted to curves he said "*it is not the oblique angle that attracts me, nor the straight line, hard, inflexible, created by man. What attracts me is the free and sensual curve, the curve that I find in the mountains of my country, in the winding course of its rivers, in the waves of the sea, in the body of my favorite woman. The whole universe is made of curves, the curved universe of Einstein*"; having as inspiration women and nature, provoking emotions in the people who see it; using geometry (he uses mainly curved lines) to give it a more aesthetic form, and to make possible the construction of such

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projects, facilitating and making possible the calculations (Fig. 1).

Figure 1. Oscar Niemeyer (Levit, 2019).

At the age of 20, he joined the Socorro Vermelho (a support organization for the persecuted and political prisoners, linked to the Brazilian communist party), later in 1928 he married Annita Baldo (descendant of Italian immigrants).

In 1929 he enrolled in the National School of Fine Arts in Rio de Janeiro; in 1930 he had his daughter Anna Maria Niemeyer; then he began his professional life in the office of Lúcio Costa in 1932, then in 1934 he graduated as an engineer-architect, later in 1936 he worked with Le Corbusier and Capanema, as a trainee and worked together with Le Corbusier to design the new building for the Ministry of Education and Public Health in Rio de Janeiro, thus demonstrating his innovative thinking giving new ideas and being accepted with success.

Later in 1937, he had his first project built in Rio de Janeiro, the project Obra de Berço, then he built the project Casa de Oswald de Andrade in São Paulo and a hotel in Ouro Preto-MG, then in 1940, he worked on the project Conjunto de Pampulha, Belo Horizonte at the invitation of Juscelino Kubitschek, where the project includes a casino, a club, a ballroom, an Englishwoman and a hotel. For the execution of this project, he worked with the structural engineer and poet Joaquim Cardoso and the landscape designer Burle Marx.

In 1942 he worked at the Rodrigo de Freitas Lake House, then in 1945 he traveled to New York to work on the design of the United Nations building and joined the Communist Party of Brazil.

Between 1951 and 1955 he worked on the Ibirapuera Park, São Paulo Surge to commemorate the 400th anniversary of the city of São Paulo, a symbol of Brazilian modernity, which was Niemeyer's second-largest project, where he used curves to accentuate the *lightness* of the buildings, In 1953 he worked on the Canoas House where he lived with his family for a long time, in 1954 he participated in the design of a group of buildings for the Hansa neighborhood as part of the Berlin reconstruction program, and he designed the Caracas Museum in Venezuela. Later in 1955, he founded the magazine Módulo in Rio de Janeiro.

Later in 1956, he was invited by JK (Juscelino Kubitschek de Oliveira) to create *the most beautiful capital in the world* where Niemeyer was able to carry out his projects together with Lucio Costa, making Brasilia a work of modern art. After that in 1963 he received the Lenin Peace Prize.

Later in 1964 due to the overthrow of the president of Brazil and the new dictatorship in Brazil, his projects were rejected and his office was raided due to persecution because of his political ideas, which stopped his career, forcing him to go into exile in Paris.

He then left the University of Brasilia in 1965 due to the military coup to highlight the difficulty of living and working in Brazil, then traveled to Paris to visit the exhibition *Oscar Niemeyer, l'architecte de Brasilia*, at the Museum of Decorative Arts of the Louvre Palace, where he received the Juliot-Curie Medal and the International Grand Prize for Art and Architecture from the magazine L'Architecture d'Aujourd'hui.

In 1967 he went into exile in France due to the military dictatorship and during his exile, he worked on different projects for different countries and obtained a special license to work in the country with all the rights of a French professional. Later in 1971, he built the headquarters of the French Communist Party, silencing critics of his style of construction.

Then in 1972, he opened an office on the Champs Elysées in Paris, where he planned the Bobigny Labor Exchange and the Le Havre Cultural Center in France. After some time, in 1980 he returns to Brazil to create the JK Memorial in 1980 and the Indian Museum in 1982, together in Brasilia, later in Rio, he builds in 1983 the Manchete Television Network, the same year in which he plans with Darcy Ribeiro, the public school system called CIEPs (Integrated Center of Public Education) and then in 1984 builds the Sambadrome, later travels to São Paulo and in 1985 builds the project Pantheon of the Homeland in the Three Powers Square in Brasilia and in 1987 the Memorial of Latin America and the headquarters of L'Humanité Newspaper in Paris. In 1988 he received the Pritzker Architecture Prize.

Later in 1991 he executed the project for the MAC Contemporary Art Museum in Rio de Janeiro and the Latin American Parliament, and then in 1996 he built the Eldorado Memoria Monument, donated to the Landless Rural Workers Movement, and the Niteroiy Contemporary Art Museum, and in 1999 he designed the new Ibirapuera Park and the Cultural Sector of Brasilia.

In 2000 he publishes his memoirs in London and creates the Ravello Auditorium, the following year he executes the project of the Brazilian Cinema Museum in Rio de Janeiro, the Oscar Niemeyer Museum in Curitiba, and the Acqua

City Palace in Moscow, then in 2002 he inaugurates the Oscar Niemeyer Museum (MON), and the Museum of Eyes, in Curitiba and projects the Ibirapuera Auditorium, then in 2003 begins the construction of the National Library and the National Museum in Brasilia, and projects the Serpentine Gallery Pavilion in Hyde Park, London.

Then in 2004 he separates from Annita Baldo and builds the Peace Monument in the city of Paris, then in 2005 he designs the Potsdam Water Park in Germany and the Hydroelectric Administrative Complex in Itapúa, later in 2006 he builds the Principality of Asturias Cultural Center in Spain and the León Brizola Memorial in Rio de Janeiro; he remarries now with Vera Lucia Cabreira. In 2007 he commits to design the headquarters of the Public Archive of the Federal District, the Museum of Image and Sound in Brasilia, and builds the University of Science and Informatics in Cuba and the Cultural Center of Valparaiso in Chile.

In 2008 he launched the third edition of his architecture magazine *Nuestro Camino* and built the Teatro Puerto de la Música de Rosario in Argentina, then in 2010, he executed the project considered the most daring of Oscar Niemeyer, the Administrative City of Minas Gerais, which was inaugurated on March 4, 2010. On December 5, 2012, he passed away at the age of 104.

Aesthetics

As previously mentioned, the aesthetics in the works is a very important aspect in the elaboration of constructions, even for a great architect such as Oscar Niemeyer is one of the most important aspects when designing his futuristic works of art, which are based on women, flowers, mountains or rather in nature, adapting their designs to the environment making something extravagant for today's architecture, but that looks good in the environment in which it is although it is more difficult to build and plan due to the calculations for the structures for its various curved shapes.

Therefore, it is important to answer the questions: What is aesthetics and how did it originate? And why are aesthetics important in the planning and construction of buildings?

The term aesthetics has different meanings. In colloquial language it refers to that which is beautiful, or rather, that which is perceived as beautiful, although in philosophy it is understood as the branch that studies the study of the essence and perception of beauty. The word derives from the Greek words *aisthetikê* (perception), *aisthesis* (sensibility), and *ica* (relative to).

Aesthetics is an artistic concept, leads to a direct connection with what we think and feel, giving it directly an abstract idea, but symmetrical can be subjective by managing objective standards.

The autonomy of the aesthetic is akin to our experience. It is not only that we can hardly equate, without roughly blurring the differences, what happens when we know a fact of the world, qualify our actions ethically or morally, or appreciate the aesthetic features of certain objects. The central point is, rather, that we do not support the relevance of aesthetic manifestations on moral or knowledge grounds: we do not say that an object is aesthetically significant because it makes us know aspects of reality or because it conforms to our ethical evaluations. Under these strict restrictive criteria we would have to take as serious deviations almost all art from Impressionism onwards and, if we look at things carefully, not a little art of the past.

Statics refers to all kinds of beauty where the person who observes it has different points of view, but there are always points in common between subjective and objective opinion, where no matter how far apart are the opinions of each person, they tend to give similar objectives.

One of them is the objective symmetry where everything you can see of an object or that you can differentiate from an object aesthetically speaking will have aesthetics as long as it is as symmetrical as possible, human beings are aesthetically attracted to objects that keep as much symmetry as possible.

If we continue talking the next point refers to aesthetics from a social point of view, aesthetics changes according to the social world where you live, and it is shown that in the eighteenth century the concept of beauty and aesthetics was completely different seeing how the social environment changes in a certain way the point of view of aesthetics.

The third point to deal with is the aesthetics through advertising, where it is one of the most important in this century, as it is determined by everything that industry wants to sell and makes it an aesthetic trend using the concept of common paranoia where a group of people influence others to follow this new concept and so on until it is quickly recognized, the problem is that as it arrives quickly changes again, but we always have an objective opinion against the concept of aesthetics because it is the one that sells us the industry.

The fourth point to discuss is aesthetics with differentiated concepts, where the concepts of aesthetics tend to be the same due to ignorance and lack of concepts, in human behavior we see how human beings in their social environment do anything to fit into a social group changing their own opinion and generating a new concept of aesthetics showing how the influence of a social group changes their whole concept of aesthetics without having their own opinion just because of their ignorance and lack of concepts.

If I speak at this point with my personal experience I would call aesthetics a concept that your family gives you, where the people you live with give you a basis of their perception of aesthetics and are the first direct influence on the way we think or feel and that makes our concept is a reflection of the first thing we see socially.

We have already seen how aesthetics in its subjective thinking has basic points that make it a general objective

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concept, where our social circles, interpersonal relationships, what they want to sell us, and the same history makes our concept similar, then we can ask ourselves if aesthetics is an own concept or is always inherited by what surrounds us? I do not know to what extent we are influenced by external values, but I can affirm that aesthetics is and will remain an objective concept with personal changes that lead to the subjective.

Why is aesthetics important in the planning and construction of buildings?

The aesthetics that Oscar Niemeyer managed to express through his long work experience in the design and creation of architectural works are of great interest, as it is one of the few visions that managed to break the predetermined schemes that were followed so far, putting firm foot managed to express what he felt comfortable light and space on more than one occasion without fear that an idea would create multiple negative impressions of that which for him was not only a structure but a unique and own art based on curved and alive strokes that gave the feeling of giving a breath to the architecture, more than that of giving a new idea that would change the way things were seen in the future, since this peculiar vision was ahead of its time by the simple fact of giving naturalness to the works added to complex futurism that endowed each structure with beauty and its character.

Just by the above mentioned it is obvious to deduce that this great designer set a benchmark for more than one, not limited only to the permission to create unique structures, but to allow new and current generations to add something more to their work, thus demonstrating that the buildings are not large piles of heavy materials, but rather a large-scale aesthetic art, which like a painting or sculpture is able to draw attention to receive time, analysis and complex opinions that demonstrate everything that was behind its creation, this vision and radical form of design already has its great impact as well as its merits and recognition by those belonging to this wide world taking steps forward on the future of it as another form of study that will be taken into account for young and new pretenders who will take advantage of this as one of the multiple paths to follow when it comes to training having a responsibility as a reference point from the moment of its arrival and possibly without a close withdrawal, Niemeyer's vision promises to be one of those that will be marked in history regardless of what happens in the following years, since things like this are rarely repeated and provoke so much from its root, that is why as for architecture, art, education and most importantly people this type of aesthetic framework has marked and will mark its own space in all media allowing it to endure and prevail as one that stood out from the rest by breaking the rigidity and creative norms and be the expressive and aesthetic artistic curve of architecture.

Interstices, construction and space utilization

Oscar Niemeyer has a very peculiar way for the planning of structures, in which he takes advantage of the interstices (small space between two bodies or two parts of the same body) to the maximum to leave more space, mainly on the main floor, to store other objects that will later be stored as equipment or large objects, besides that the structures built with interstices are built with a height of approximately 6 to 8 floors to have easy access to repairs and not have to completely close the building for repairs.

We can observe that Oscar Niemeyer in his projects uses modernist architecture combining it with interstices to demonstrate how by making good use of a space a work of art can be generated, as in the cathedral of Brasilia (Fig. 2).

Figure 2. Cathedral of Brasilia (Mangini, 2019).

In which, to take advantage of the space and interstices, and not to *damage* or modify the structure, he designs a subway entrance; With a height of 40 meters, with a large space between the center and its structure, and with independent structures, it allows the entrance of various large objects, to arrange the space as desired, and to change the objects without any problem, besides that, it gives a great futuristic style very interesting and attractive, and most importantly, it allows that if a repair is needed in any of the pillars, it is not necessary to close the entire enclosure, but it can continue to be used while it is being repaired.

Basis in Niemeyer's aesthetics

Start of his vision

How was the concept of aesthetics born for Oscar Niemeyer? We see this reflected through the different texts cited for this article, different types of informative texts were used in addition to interviews with Niemeyer. This text may sound unremarkable to some readers because of the question asked and because not everyone knows the person to whom this text refers, His vision begins from the point of work which began as that of any person of our days and of the past times. He started as just another architect of Brazil who was one of the creators of the Brasilia project which at first did not go as expected and he was criticized by many of his colleagues and superiors because of this he had to seek new opportunities in Europe more specifically in France where he polished all his knowledge and acquired new techniques developed in the old continent, He returned to his native country to implement everything he learned to be recognized today for his many works not only in Brazil but in more than 20 countries and four continents this gives us to see how Niemeyer took his architecture around the world.

This gives us to understand that for Niemeyer architecture is to create, it is not simply designed if not give way to something new something never seen before something out of the ordinary construction. With this in mind gives us to understand the importance of the question posed in this text, as it is to know the point of view of someone so important and influential in the architecture of all time that not only should be his point of view but to be so important his work should be a concept that takes into account any architect of the modern era. But we can always open a door to debate and ask ourselves if Niemeyer's definition of aesthetics is the correct one.

We find another very interesting phrase of Niemeyer that shows us how imagination influences architecture and aesthetics and how this is reflected in every project that an architect carries out. And this leads us to underline what is the contribution of this text to the readers is that they know more deeply what architecture means, which is not only a combination of engineering and the erection of walls but can be defined as an artistic expression on a large scale.

Niemeyer was a complete revolutionary as far as architecture is concerned since all his works were completely different from what had been seen until that time. Why? Niemeyer visualized a different aesthetic for the constructions since at that time everything was generally straight-line constructions.

He innovated by including curves in concrete structures since for many this was impossible and far-fetched due to the hardness of concrete and the fear that by not being straight the structure might not have the same resistance capacity offered by a straight structure.

Among his most outstanding works, which include curves, we can appreciate the Oscar Niemeyer Museum, the Museum of Contemporary Art, and the Cathedral of Brasilia. But we must keep in mind that Niemeyer did not reach the summit by himself, since after his exile in France he returned being still questioned for his type of architecture, here we go back to 1932 when he joined Lucio Costa who was an architect who like Niemeyer was in the pilot plan of Brasilia, these two had a partnership that lasted for years forming several projects among which stands out the Gustavo Pacanema building.

Lucio Costa lived until 1998, but even so, Niemeyer continued with his life as an architect working in his field despite his advanced age and continued with his life as an architect until his death at the age of 104.

The architectural revolution resulting from its aesthetics

Taking into account that the texts that can be found today on Oscar Niemeyer are several and you can also appreciate his projects that mentioned above were a complete revolution for the time. His works have been the inspiration for many architects of the modern era who have his projects and his life in general as a reference to follow. This revolution has much to do with the question posed, as it shows the importance that aesthetics had in each of Niemeyer's works.

Niemeyer's influence on architecture is such that even a culture such as the Japanese has been inspired by this master. I want to highlight a little in this area that I find very interesting because the Japanese culture has always been considered a highly advanced culture compared to the rest of the world. This is because their strict discipline makes them the best professionals in many fields of work.

And see how Niemeyer influences the architectural field of this culture makes us see how the aesthetics in the architecture of Niemeyer did not remain as something for the simple view and appreciation of all those who saw his works, but what he sought was to convey a revolutionary idea that would lead more architects to be launched by innovation and not stay in the field of the straight line that was the regime that had the architecture before his time.

One of his greatest influences was Le Corbusier, since Niemeyer's ingenuity was not a flash that came out of nowhere, Le Corbusier was a complete theorist who knew how to transmit his buildings to other professionals and this gave rise to Niemeyer's ideas of not just building without including art or even building without taking into account some of the philosophy of this area of work.

This makes it more than clear what Niemeyer wants to convey, he makes his works so that others notice that they are unique, his architecture has always been marked by the use of curves that he, being a passionate man and lover of women, implies that he is inspired by it to make his works.

Another reference to the fact that Niemeyer looked at the world with different eyes than other people, since he

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could see the beauty of his surroundings from the simplest of things, and when he saw the beauty of the universe, he captured its beauty in his revolutionary works of art.

Let's look at another of his many important works and where his vision of aesthetics can be seen reflected in the city of Brasilia, which became the new capital of Brazil in 1960. This city was one of Niemeyer's favorite canvases, it was enough to see that together with Lucio Costa they were practically the creators of this city that were innovative and would bring a lot of progress to the nation.

Let's say that this was the first time that Niemeyer decided to carry out structures with curves and that I thought to show the signs of a career that would be full of success and that would define a new concept for the architecture of all history. He took into account that this had to be a location that would be even for the president's compound. Despite the short time he had for its construction, he realized that he had created a new architecture that took to another level what was known until now about construction. He broke the mold of flat construction and gave way to a new type of structures that were based on aesthetics and curves which could transmit to everyone who saw it that innovative thought of staying in what has been working for years that we can do more to take not only the architecture but every aspect of our lives to another level to something that revolutionizes society as we know it now.

We can see that what we have talked about not only serves as a topic for enterprising architects but for anyone who has a different way of thinking that breaks the mold. This also helps us to see the beauty of the world and not only have aesthetics as something visual but as something that goes beyond the simple human vision that through it we can express ourselves and bring a message to other people who may be looking for a meaning to the present and life.

Niemeyer an exemplary visionary?

First, given the contexts seen during this chapter, it can be defined that aesthetics for Niemeyer is the most fundamental part of a structure since it can transmit thoughts to anyone who truly admires it with more than just sight. Now let's go to one of the faces of Niemeyer less known by many people.

Let's talk about Niemeyer's ideological thinking and how with his works he talked about communism. Someone who had a thought inspired by Marx and Lenin, but who treats it more as a moral value than as a way of doing politics this does not make us see the other as a friend walk side by side with our companions and not see them as rivals and try to make them fall on the way.

Niemeyer was also part of the communist party of his country until it fell in the coup d'état in 1964 where Niemeyer was exiled again due to his ideology, despite this it is seen that he was a friend of the Cuban communist Fidel Castro and we could say that he shared some ideas (Fig. 3).

Figure 3. Dead Fidel Castro, when Niemeyer remembered their meeting and the anti-Castro lawyer (Terruzzi, 2019).

Here he shows us that Niemeyer was not only a revolutionary in terms of architecture but also participated in trying to revolutionize a bourgeois thought that began in the city of Brasilia which he decided to leave because the powerful and wealthy people began to come to the city to settle there. After his exile, he left for France where he was from 1964 to 1985 where he designed some of his works such as the headquarters of the Communist Party in Paris and the House of Culture in Le Havre. He also did some works in Algeria where he also managed to become an architectural reference in this culture. After he died in 2012 the world mourned the loss of a great exponent of the architecture of the last centuries.

Niemeyer died in a hospital in Rio where he was hospitalized due to health problems due to his advanced age, specifically dehydration. Several countries and organizations spoke about Niemeyer in tribute to his passing. Among them Unesco and the UN, which referred to him as a *major figure*, *universal artist* and *great humanist*. This makes it clearer that even for world-class organizations Niemeyer was an exceptional artist and architect of the kind that will rarely be seen again in history. For Unesco, his greatest work (Brasilia) has been a world heritage site since 1987.

A country that admires Niemeyer as much as Cuba also teaches us that his communist thinking was also an example of how the reality in which we live should be. Niemeyer died as probably the greatest architect who ever lived. And he died leaving clear what he wanted to show with his architecture, with his aesthetics. We conclude by saying that for Niemeyer the essence of a structure was in its aesthetics that could transmit ideas and emotions to anyone who saw it, which is beyond a simple set of walls.

Oscar Niemeyer, architectural visualization

Architectural concepts

What is the relationship between construction and aesthetics according to Oscar Niemeyer? Oscar Niemeyer leaves a legacy to those studied that is based on the concepts that he put forward throughout his career as an artist and as an

architect. His architectural conceptual principles are based mainly on the use of light in external or internal spaces and geometry in plans and constructions.

According to the preceding, it can be said that the relationship between construction and aesthetics for Oscar Niemeyer is the background of the constructions, how they can express feelings, and the interpretation that each person can give to them. He was an exemplary architect, influenced by Le Corbusier, Lúcio Costa, and Carlos Leão, thus participating in the mega-project of Brasilia. Here he learned about the artistic and technical articulations that converge to the breadth of pragmatic compositions in all their splendor. He also innovated in production and construction methods such as concrete, which facilitated the use of curves in the constructions, being a highly flexible and resistant materia

A further important factor of Niemeyer's modernist methods was the use of space and the preservation of the natural aspects or in simple words the surrounding landscape, mainly in the use of flora and water resources (this without affecting in any way what was already planted). This could be developed by the multifocal methodological system; which made easier the relationship between modern language and the global conceptualization of the new methods or forms of architecture.

He always stood out from the rest, since he always imposed his stamp on any work he did, thus highlighting the culture of his country, his masters, and above all his spectacular magic when imagining basic works in meticulous works full of details and altruism. In this way, Oscar Niemeyer managed to innovate in a field that already had its bases and well-established arguments, demonstrating not only methods but also concepts that something as great as constructions can only need a different perspective and ingenuity.

Niemeyer's construction methods

Architecture is an invention. Based on this premise is that projects can be made, always in search of beauty, expressive solutions, different, capable of surprising. The architect is a citizen like any other, always open to attend all kinds of programs that are presented to him, he must remain attentive to the need to change society, to carry out a more just and supportive world. With drawings and stories of the architect himself, it faithfully reflects the delicacy with which he worked. Niemeyer is always based on the observation of nature and the curves in his constructions (Fig. 4).

To contemplate all this at the time of the creation of a work, he had to take into account different aspects such as:

- Resistance.
- Durability.
- Support.
- Space management.
- Adaptation to the structure.

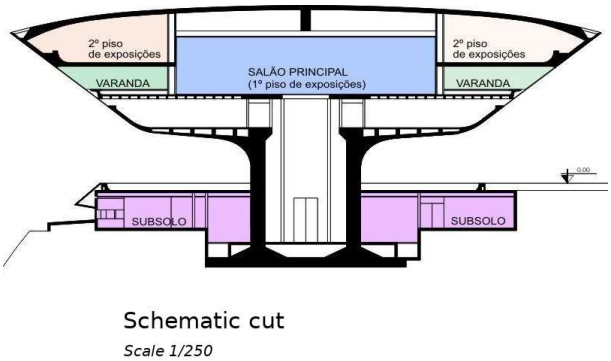

Figure 4. The Niterói Contemporary Art Museum (Wikiarquitectura, 2019).

- Costs and budgets.
- Etc.

Since he was a qualified engineer-architect he could participate in both areas (construction and creation), with those concepts established and from his knowledge, he began to visualize construction methods and forms differently, since he started to develop his architectural constructive concepts.

He proposed a uniform division of weights in columns that did not affect the internal space, in which the loads did not alter any form of the structure. From the concrete, it was easier for him to build works with different patterns in their bases and even with a variety of foundations with greater complexity that lead to parameters so that their forms were from the narrowest base to its much larger and more uniform structure.

Oscar revolutionized civil constructions in every conceivable and unimaginable way, transforming the ways and methods in which they were produced or built, exploring more and more what was unthinkable at the time, challenging the established construction norms, and showing that despite the complexity of construction, it can be done with enough knowledge and courage.

He never flinched from any construction and devised other ways to make it happen, using the plans he represented an abstract idea, it was very unusual to observe in his drawings any construction with patterns or rectangular shapes.

Utilizing the longitudinal cuts he reflected how the spaces and rooms would be organized, by the transversal cuts he denoted the way to access the different rooms and the area they had. Without forgetting the perspectives of his buildings, depending on the angle at which his constructions were observed, one could see a different figure in his work and thus astonish the *spectator* even more.

He believed that everything important was born in sensibility. One expresses oneself within a limited field, by the terrain, by the form, by the efficiency of construction. One also leaves one's personal history in the work, as André

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Malraux said, *what one has seen and loved in life*, and architecture is like that. Each work, even if unintentionally, contains the memory of older architecture, of previous forms, of people, the memory of a beautiful woman, of a history.

For him the inspiration of women was very important, he defined them as perfect works that the more curves they had the better, he thought that they were highly complete works of art, that their mere presence was admirable and that based on the curves of women his planning of the works was going to move towards a better future.

So Niemeyer did innovate in the way of building and planning every aspect of a work, changing how a building was observed, transforming everything established in terms of art, and demonstrating that architecture is not based on the elaboration of mundane works.

Aesthetics for Niemeyer

Aesthetics is the study of art, its qualities giving an origin to the feeling and the creations that it reflects, creating certain judgments and general experiences making reflect on the value contained in art and everyday life. Plato said that aesthetics is something beautiful in itself and something good in itself, Kant referred to aesthetics as a philosophical branch that analyzed the manifestation of the expressive and beautiful visually, and finally for Buenaventura de Fidanza aesthetics for him in the name of God was everything to be considered with proportionality in its concept of form, it is called beauty, beauty and delight do not exist without certain proportion, and this primarily consists of the number.

For Niemeyer aesthetics was the faithful representation of his ideas, that is to say, that the aesthetic is subjective, but there are points in common of what can surprise a person, for Niemeyer mainly as mentioned is the conservation of nature and the curve of the figures.

Niemeyer's way of innovating was based on architectural concepts and diverse construction methods that he influenced, created, and introduced from other cultures. He caused such a global transformation both politically and socially that modern buildings began to develop a certain type of aesthetic. His influence today is extraordinary, he is one of the greatest architects in history, and is a source of pride for Latin America and the world.

Niemeyer's modernism is characterized by his famous cult of the curve, but also, the curator points out, by his eagerness to integrate his buildings with their surroundings. The vegetation is always integrated and is an accomplice of the buildings and their intended use.

With a deep understanding of solidarity, the architect, defender of freedom and human rights, created flexible, curvilinear modernism, of forms inspired by the biological with a rhythm and a composition free to the fanciful imagination. A modernist who went beyond the rules.

He was a great exponent of all those innovative artists, a revolutionary in the matter and with a born ingenuity he demonstrated that the power of the limits to the imagination is put by the one who imagines, he never limited himself nor limited any of his companions, he was Christopher Columbus of the constructions, discovering new ways to build in different lands.

In summary, Niemeyer managed to relate aesthetics and constructions from the methods he proposed and found in common the way to surprise people, not contemplating the building as simple pieces of construction but as works of art that could be detailed in its maximum expression.

Conclusions

Niemeyer was characterized by the use of curves, the entrance of light, and also the appropriation of nature. He was an innovator in architecture and constructions since he revolutionized this by giving a different perspective to the way they were planned or built, changing even the methods, but especially the norms. Through his arduous experience, collaboration, or apprenticeship with various architects, and external influences the learned and influenced that the aesthetics of a building is reflected in its architect, in the ingenuity he possesses and demonstrates the way he can see the world.

For Niemeyer geometry was highly important since it was based on the figure of the woman, he described it as perfect and started from it in terms of planning his works; making it much more detailed and varying the symmetry, demonstrating the importance of the external point of view to observe the beauty of the form and the contemplation of the work in its splendor.

Space and the interaction between people were important to Niemeyer, he was interested in the way people moved around, so in the internal structure, he sought to ensure that the structure did not affect the internal emptiness of a floor.

For Niemeyer, aesthetics and constructions are mainly related, and from the background of the constructions, how they can express feelings and interpretation are based more on the subjectivity of each person and the taste they can demonstrate. Niemeyer, despite all the difficulties he experienced, learned that he who gives up halfway will see others fulfill the dream he set out to achieve, but will never achieve it, so he did not give up and worked until his death. He lived and fulfilled his dream, never regretted anything, and believed that the decisions he made could not be regretted.

Niemeyer's surprise factor in his works was what most fascinated the students since up to the last deadline for the presentation of the plan, he delivered the plate with models different from the expected one.

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Design and evaluation of Volume Unit (VU) meter from operational amplifiers

Diseño y evaluación de vúmetro a partir de amplificadores operacionales

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A VU meter is a volume level indicator device used in audio equipment. Its function is to show the user the signal level in volume units. By construction, this device displays a rectified sample of the audio signal voltage. However, the VU-meter does not measure the input voltage, but rather a reference of the average volume in decibels. This visual indicator was introduced in the 1940s as a way of normalizing levels on telephone lines, but it became a visual indicator of the amplitude of the input signal that was pleasing to the eye because of its synchrony with the music. Consequently, digital versions have been introduced as a replacement for analog schemes with LED (Light Emitting Diode) displays that provide more information and greater visual effect. In this paper, a simple operational amplifier (Op-Amp) based VU-meter design is proposed.

Keywords: Design, electronic instrumentation, operational amplifier, VU meter

Un vúmetro es un dispositivo indicador de nivel de volumen utilizado en equipos de audio. Su función es mostrar al usuario el nivel de señal en unidades de volumen. Por construcción, este dispositivo visualiza una muestra rectificada del voltaje de la señal de audio. Aun así, el vúmetro no mide realmente el voltaje de entrada, sino una referencia del volumen medio en decibelios. Este indicador visual fue introducido en los años 40 como forma de normalizar los niveles en las líneas telefónicas, pero se convirtió en un indicador visual de la amplitud de la señal de entrada agradable al ojo por su sincronía con la música. En consecuencia, se han introducido versiones digitales como reemplazo de los esquemas análogos con visualización LED (Diodo Emisor de Luz) que brindan mayor información y mayor efecto visual. En este artículo se propone un simple diseño de vúmetro basado en amplificador operacional (Op-Amp).

Palabras clave: Amplificador operacional, diseño, instrumentación electrónica, vúmetro

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Introduction

A Volume Unit (VU) meter is a device that was used in speech research before current digitization strategies and digital instrumentation (Lobdell & Allen, 2007). Its importance was such that standards were developed for its design and use (ASA 1954, ANSI 1969) (Blaeser & Struck, 2019; Edgerton, Beattle, & Helmerich, 1982). The function of these devices is to visually represent an acoustic power level in the average and peak value ranges reflecting the amplitude and frequency behavior of the acoustic signal (mainly human voice and music). These analog needle instruments, however, had many shortcomings in terms of reliability, and it is well known that the readings of one user for a given audio sample are not repeatable by another user, causing different individuals to have different readings for the same sample (Killion, 2009).

The adjustment of a VU meter is performed by mapping the RMS (effective sound pressure) sound pressure of a 1 kHz signal to a deflection in the VU meter corresponding to the speech signal (Schmid, 1977). Therefore, there is no real 1 vu calibration in the instrument. The instrument unit, called vu, is a unit defined to characterize the volume, which is an average electrical power level. From this point of view, the VU meter is a kind of voltmeter calibrated in such a way that the user can observe and measure a certain power level.

The initial use of this instrument was to verify the power level in the twisted wire telephone lines, which after long distances lost power in transmission. The test and measurement were performed by transmitting voice over the telephone line according to a pre-established program, and the VU was used to check the transmission peaks at the other end of the line. In the sound players, this device provided a visual representation of the music that has been maintained to date with much more striking visual systems, which has led to its current design with new technologies and adding the visual element (McGowan, Leplatre, & McGregor, 2017). This type of visual indication is also used in other types of measurements (Feier, Enatescu, Ilie, & Silea, 2014; Muliawan, Nahar, Sebastian, Yuliza, & Khairurrijal, 2015; Nair, 1965).

Due to their functional nature, operational amplifiers (Op-Amp or OpAmp) become the ideal device for the design of VU meters (Jacinto, Montiel, & Martínez, 2017; Rendón, 2019). These circuit devices are ideal for electrical signal conditioning and instrumentation due to their high input impedance, low cost, and simple configuration for handling continuous signals, such as small voltage levels (Garcia, Osuna, & Martinez, 2018; Gordillo & Martínez, 2018; Martínez, Rendón, & Arbulú, 2018). They are typically used as an intermediate stage between a sensing system and a digitizing system and can even be used for digital implementations (Martinez, Montiel, & Martínez, 2018).

Problem statement

It is desired to develop a five-stage VU meter whose structure is based on OpAmp. Each stage functions as a voltage comparator, taking as input reference a portion of the supply voltage through a resistive divider. This reference voltage is compared with the audio signal to scale its average RMS value and turn on some LEDs (Light-Emitting Diode) proportional to the estimated input value. The circuit will be powered from a dual constant source of ±10 Vdc, the design value for the electronic components of the circuit.

Fig. 1 shows one stage of this design. At the output of the OpAmp, a 220 Ω resistor is connected in series with a rectifier diode, which in turn is in series with an LED. This has the function of further limiting the range of the output signal from ±10 Vdc to a range of 0 - 10 Vdc. This occurs as a function of the rectifier diode, which essentially acts as a one-way switch for the current.

When a positive saturation voltage (V_{sat}) is present, it is satisfied that:

$$V_{sat} = V_{in} - V_{ref} \tag{1}$$

$$V_{in} > V_{ref} \longrightarrow +V_{sat} \tag{2}$$

Under this condition, the rectifier diode is conducting, therefore the LED is turned on (LED = ON).

Fig. 1 shows the diode of the circuit in conduction since it fulfills equation 2. Applying equation 1, and assuming that the input audio signal has a value of 12 Vdc (input to the positive terminal of the OpAmp), we have that:

$$V_{sat} = 12 - 10 = 2\,\text{Vdc} \tag{3}$$

Therefore:

$$12\,\text{V} > 10\,\text{V} \longrightarrow +V_{sat} \tag{4}$$

If, on the other hand, the V_{sat} is negative, then:

$$V_{in} < V_{ref} \longrightarrow -V_{sat} \tag{5}$$

Fig. 2 shows the diode of the circuit in interruption, since it fulfills equation 5. Applying equation 1 we have that:

$$V_{sat} = 5 - 10 = -5\,\text{V} \tag{6}$$

Therefore:

$$12\,\text{V} > 10\,\text{V} \longrightarrow -V_{sat} \tag{7}$$

This means that the rectifier diode is unable to conduct, and therefore the LED is turned off (LED = OFF).

This block constitutes the basic structure of the circuit. To complete the design, similar structures are added in parallel but fed at the negative terminal of the OpAmp with a different value of reference voltage. These reference voltages are

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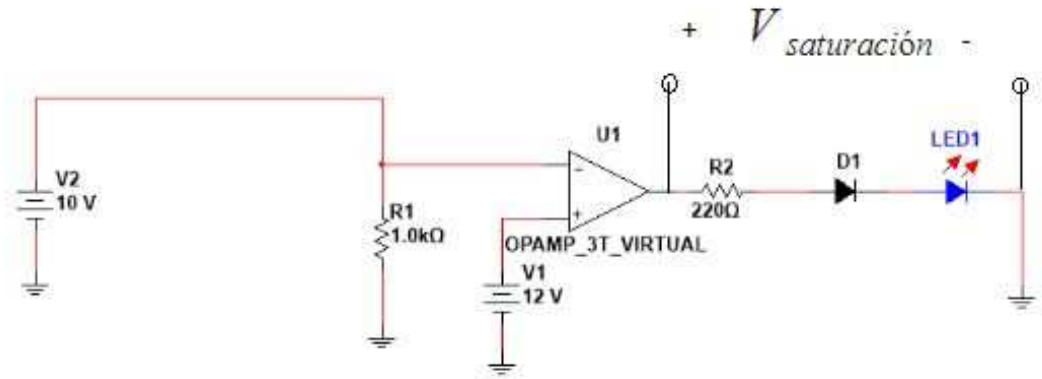

Figure 1. Saturation voltage positive, diode in conduction, LED=ON.

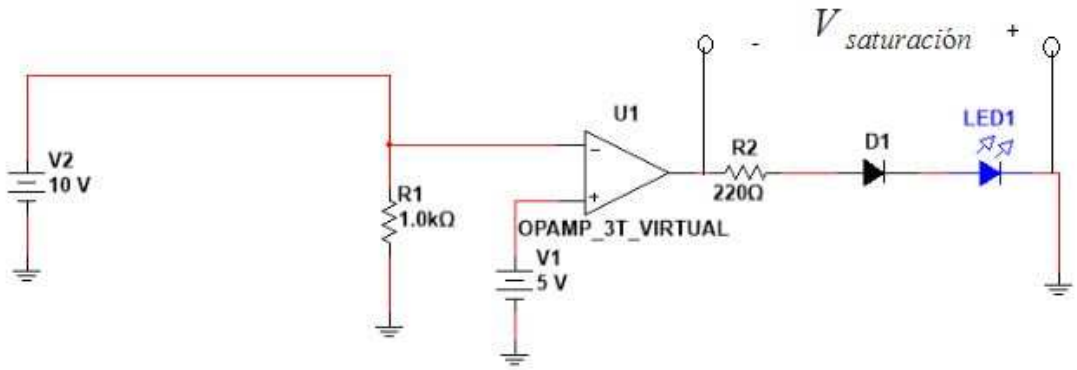

Figure 2. Negative saturation voltage, diode in interruption, LED=OFF.

proportions of the voltage used in the first block, which can be achieved using resistive dividers. For example, to add a second stage, the second block can be fed with a resistive divider that feeds half the voltage used in the first block (Fig. 3).

In this new circuit, we can observe several changes. The reference voltage V_{ref} of the circuit for OpAmp 1 has changed and was reduced to half the supply voltage $\left(V_{ref} = \frac{10}{2} = 5\,\text{V}\right)$, and OpAmp 2 has an initial reference voltage $V_{ref} = 10\,\text{V}$. The reference voltage of the circuit behaves like a resistive divider, so the reference voltage for each amplifier is a proportion of the total voltage.

$$V_{ref} = 10 \times \frac{R_1}{R_1 + R_2} \tag{8}$$

In Fig. 3 we can see that the two LEDs of the circuit are turned on, this is because the input voltage that simulates the audio input is higher than the total reference voltage.

The circuit in Fig. 4 shows a completely different picture. In this case, the input voltage simulating the audio input is lower than the total reference voltage, which becomes a negative saturation on OpAmp 2, and therefore the rectifier diode is interrupted (LED = OFF). However, for OpAmp 1 this reference voltage is lower than the input voltage, and therefore in this case the rectifier diode is activated and presents conduction (LED = ON).

These behaviors provide the basis for the design of our VU meter.

Volume Unit (VU) meter design

The proposed design for the OpAmp-based VU meter circuit is shown in Fig. 5. Two key elements were considered for this design:

1. The input voltage (audio signal as voltage from the acoustic source) must be higher than the reference voltage for the rectifier diode to conduct and the LED = ON.

2. The reference voltage fed to each OpAmp block is different according to the position of the element within the circuit in coherence with the desired display of the input signal. For example, for the lowest block, it must be fulfilled that:

$$V_{ref(\text{level 1})} = \frac{V_{total}}{5} \tag{9}$$

This proportion is fulfilled because it is desired that the five resistors are equal. If this is not the case, we must

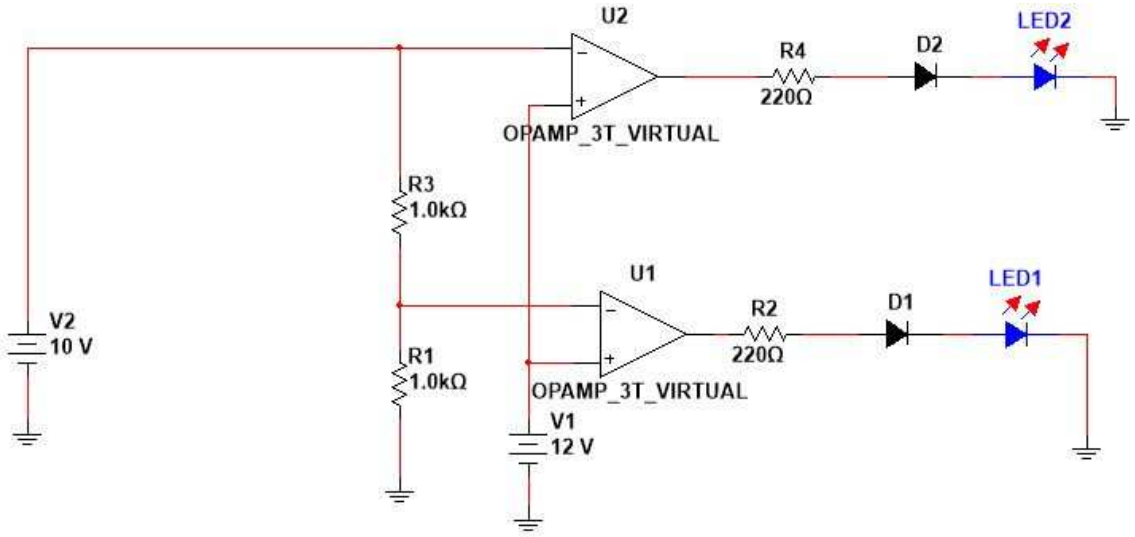

Figure 3. Simulation, coupling of a second amplifier, LED1=ON and LED2=ON.

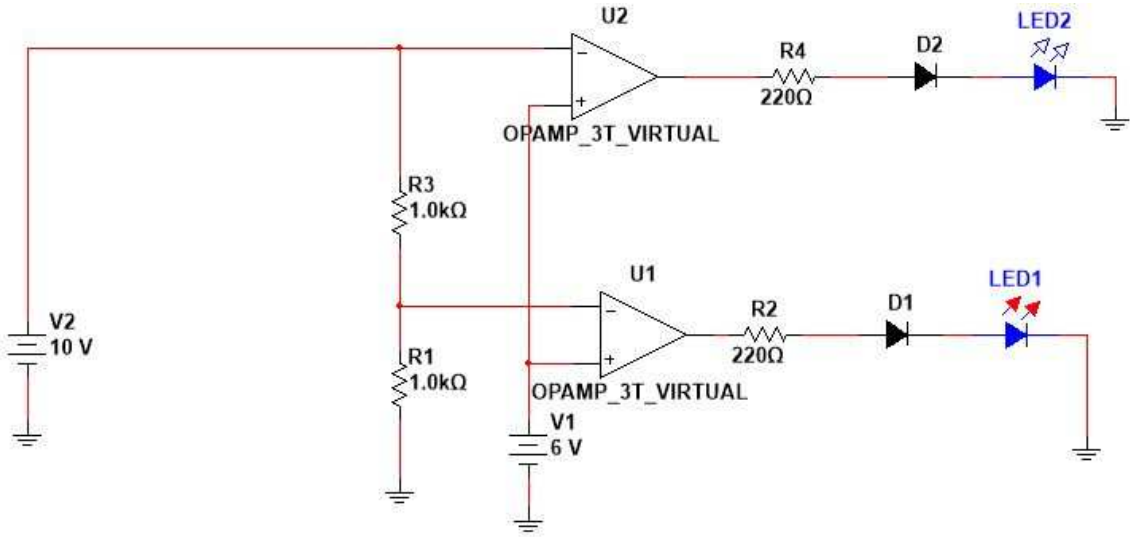

Figure 4. Simulation, coupling of a second amplifier, LED1=ON and LED2=OFF.

calculate the respective voltage values. In Fig. 6, we can confirm that this ratio is indeed fulfilled.

The circuit corresponds to an indicator device, therefore the LEDs indicate when the reference voltage (in this case 10 Vdc) and its proportions have been exceeded by the input voltage (the audio signal). This indicator consists of intermediate levels, so it not only shows when the level is higher than the maximum (all LEDs = ON) or minimum (all LEDs = OFF), but it is also able to measure, for example, when the input voltage is equal to $\frac{3}{5}$ of the reference voltage (LEDs 1 and 2 = ON), and so on, until it reaches the top which is when the input voltage is greater than $\frac{5}{5}$ of the reference voltage (all LEDs = ON).

Currents on resistors

As is well known, the input impedance in OpAmp is very high, therefore the current they draw is minimal and can be neglected. Thus, the current passing through the 1 kΩ resistors is equal to:

$$I = \frac{V_{ref}}{\sum_{i=1}^{5} R_i} \tag{10}$$

Applying equation 10 we have:

$$I = \frac{10}{5000} = 2\,\text{mA} \tag{11}$$

These values can be verified by simulation regardless of the value of the input audio signal (Fig. 7).

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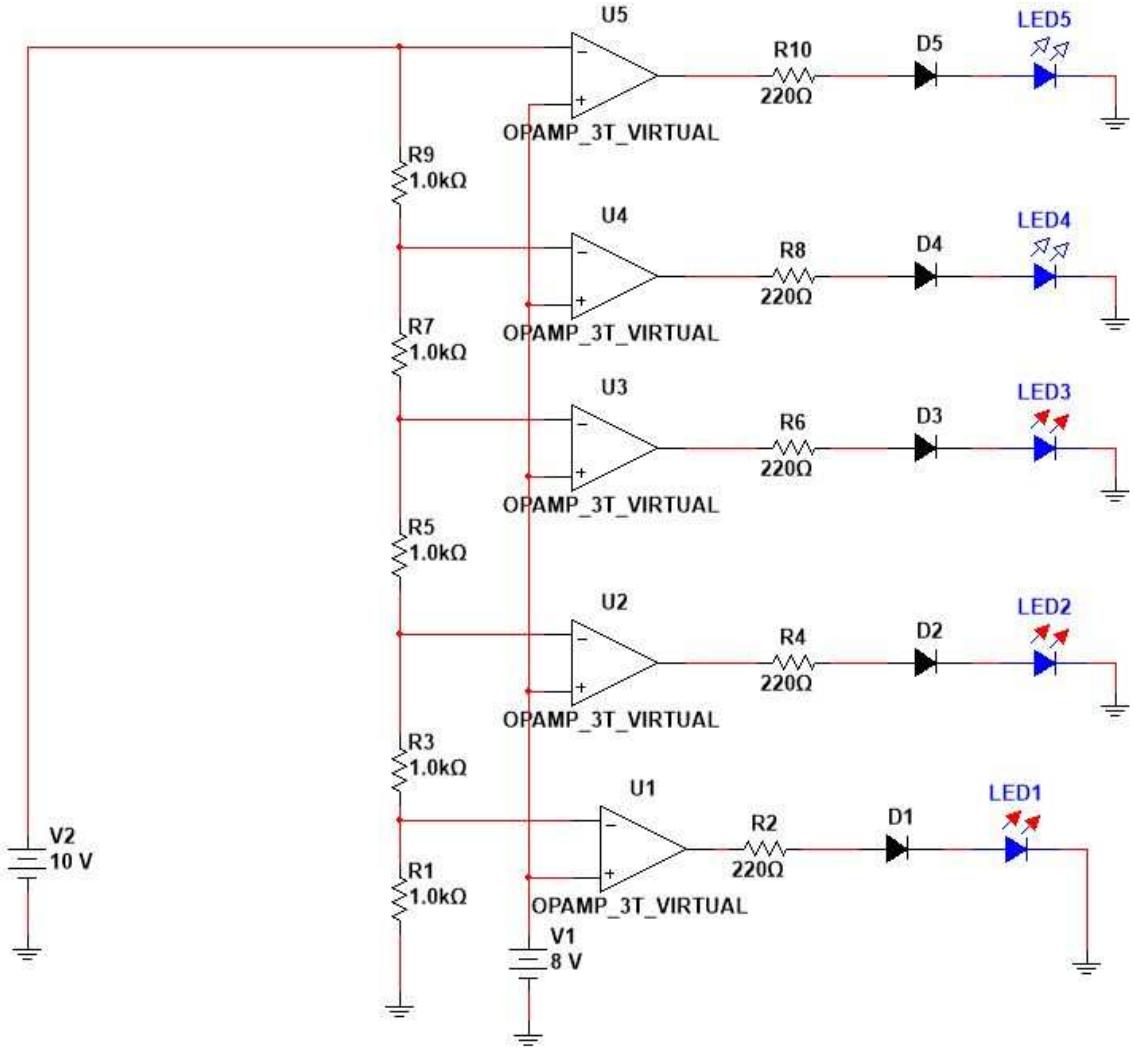

Figure 5. Full circuit simulation, input voltage $V_{in} = \frac{4V_{ref}}{5}$.

This is a standard symmetrical design, where all resistors have the same value, and therefore there is a constant $\triangle V$ between each reference of each OpAmp. However, according to user needs, it is possible to change the value of the resistors. If, for example, the value of the resistors changes, and they all remain equal to each other, but different at 1 kΩ, then two cases can occur, where the current decreases:

$$I \downarrow = \frac{10}{R_{total} \uparrow} \tag{12}$$

Or increase the current:

$$I \uparrow = \frac{10}{R_{total} \downarrow} \tag{13}$$

Because the source voltage is constant, the reference voltage at each level tends to remain constant as well. The decrease in current is compensated by the increase in resistance.

If the value of the resistors changes and they are different from each other, the reference voltage at each OpAmp will depend on the resistance values of the resistors. The ratio of the reference voltage used for comparison at each stage would no longer be constant.

Rectifier diodes

When the input voltage is higher than the reference voltage, the following occurs:

$$V_{in} < V_{ref} \longrightarrow -V_{sat} \tag{14}$$

The differential voltage is negative, and we will have a negative saturation voltage. In this case, the rectifier diode does not allow the LED to turn on, since by nature a diode

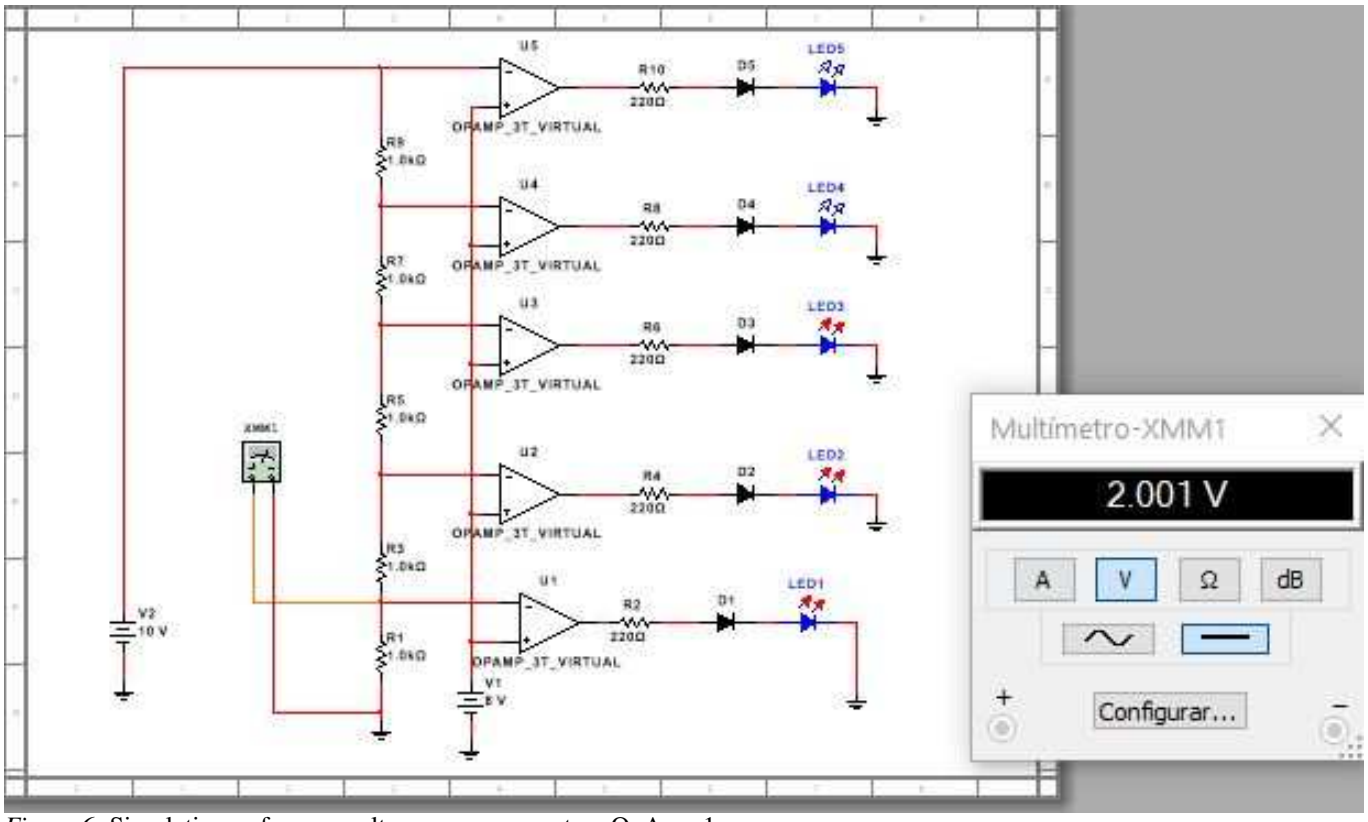

Figure 6. Simulation, reference voltage measurement on OpAmp 1.

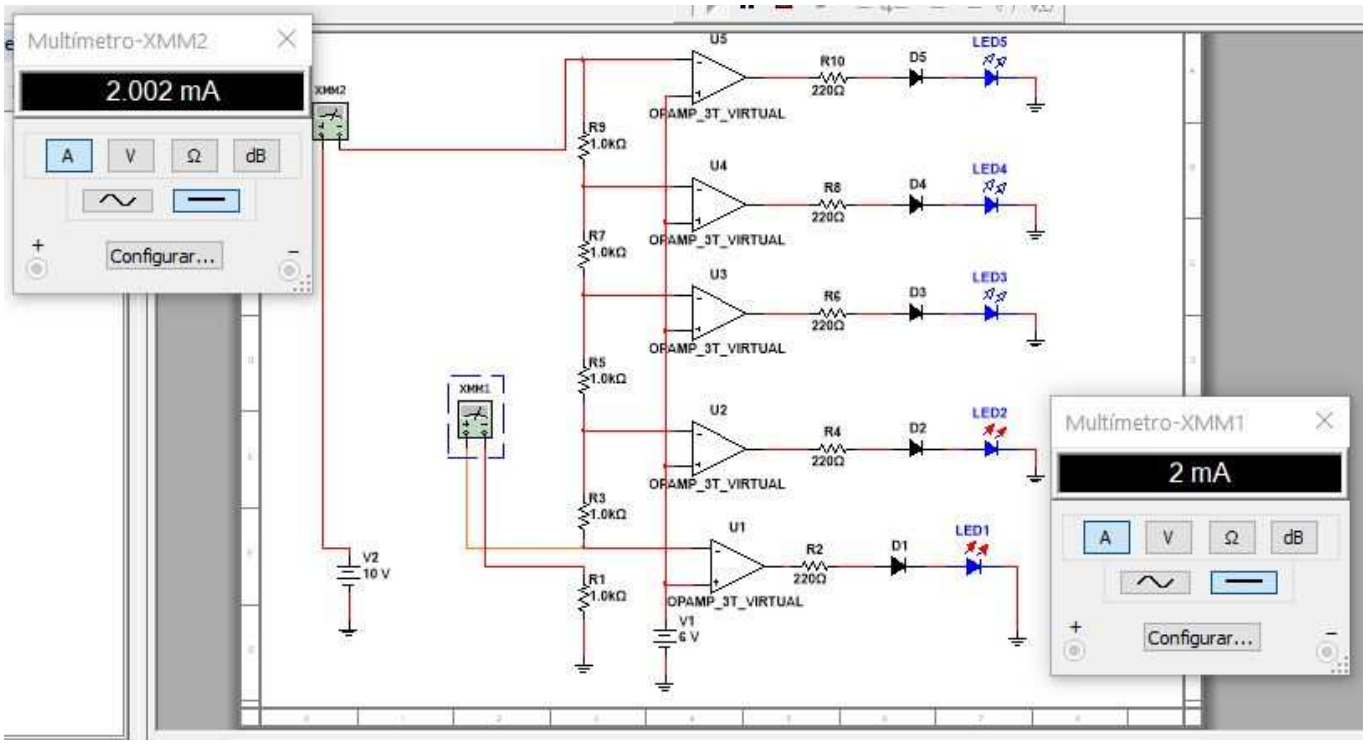

Figure 7. Simulation, current measurement through 1 kΩ resistors.

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is a semiconductor device that acts essentially as a one-way switch for current, and with voltage polarity for activation.

OpAmp supply voltage

In case of the OpAmp supply voltage changes, we would have an increase in the saturation voltage, and therefore an increase in current through the 220 Ω resistor that is in series with the rectifier diode, and turn in series with the LED. If the 220 Ω resistor is maintained, the output voltage increases, and thus the current, depending on how much current the LED can withstand, could burn out. If this power supply is separated from the reference voltage, there are no functional changes in the circuit, the comparison voltages at each stage remain the same, despite changing the output voltage (saturation voltage) of each OpAmp.

For the actual circuit assembly, it is possible to use an OpAmp such as the LF353. This is a low-cost device with JFET type input (high input impedance, in the order of $10^{12}\,\Omega$), short-circuit protected output, and with wide availability in the market. The power supply range of the device is ±18 V, which implies that it can well be used in our design.

If the circuit is implemented with this OpAmp, what would happen if the LF353 operational amplifier is biased with a simple 10 V source, that is if the -10 V source is replaced by a connection directly to the ground? If this were to happen, the saturation voltage would always be positive, it would oscillate between 0 and 10 V, which is the same as it currently does because of the rectifier diode.

VU meter design under functional requirements

In this section, as an example, we seek to design the VU meter circuit so that a maximum voltage of up to 5 Vdc can be displayed on the LEDs, in steps of 0.5 Vdc per LED. The current through the resistive divider should be 2 mA. The LM324 is to be used for the implementation.

In this case, it is intended to work with the LM324. This OpAmp is characterized by working with a single power supply with a range from 3 V to 32 V. Operating in the linear zone, the common-mode input voltage range includes ground. The output voltage can also approach the ground, even when working with a single supply. The unity frequency gain is temperature compensated. The input bias current is also temperature compensated.

Among the features of this OpAmp we can detail the following ones:

- Internally frequency compensated for unity gain.
- High DC gain (100 dB).
- High bandwidth (unity gain) 1MHz (temperature compensated).
- High power supply range.
- Single supply between 3V and 32V.
- Very low current consumption (700 μA) independent of power supply.
- Very low input bias current (45 nA) (temperature compensated).
- Low input voltage offset (2 mV) and current offset (5 nA).
- Common mode input voltage range includes ground.
- Input differential voltage range is equal to supply voltage.
- Maximum output voltage excursion: from 0 V to V+ - 1.5 V.

Based on the above characteristics of the LM324 amplifier, the general characteristics of operational amplifiers can be modified in circuit simulation software to evaluate the performance of the element. The tests in our case were performed in NI Multisim, an electrical circuit simulator based on Berkeley's SPICE simulator. The test setup considered the following parameters.

High DC gain (100 dB)

The gain is calculated as follows:

$$100\,\text{dB} = 20\,log_{10}\,(A_V) \tag{15}$$

$$A_V = 10^5 \tag{16}$$

Bandwidth (unity gain)

According to the manufacturers, the value is set at 1MHz.

NI Multisim configuration

The final configuration used to replicate the behavior of the LM324 in NI Multisim is shown in Fig. 8.

Design criteria

The following are the criteria used for the design sought.

$$I_R = 2 \times 10^{-3}\,\text{A} \tag{17}$$

$$V_{source} = 4\,\text{V} \tag{18}$$

$$R = \frac{0.5}{2 \times 10^{-3}} = 250\,\Omega \tag{19}$$

$$\text{Number of resistors} = \frac{4}{0.5} = 8 \tag{20}$$

With these parameters, it is possible to implement the entire VU meter circuit. To verify the performance, eight blocks of the circuit were implemented with eight LM324 OpAmp, as well as a resistive divider consisting of eight resistors of 250 U each. The operating point of the circuit can be seen in Fig. 9.

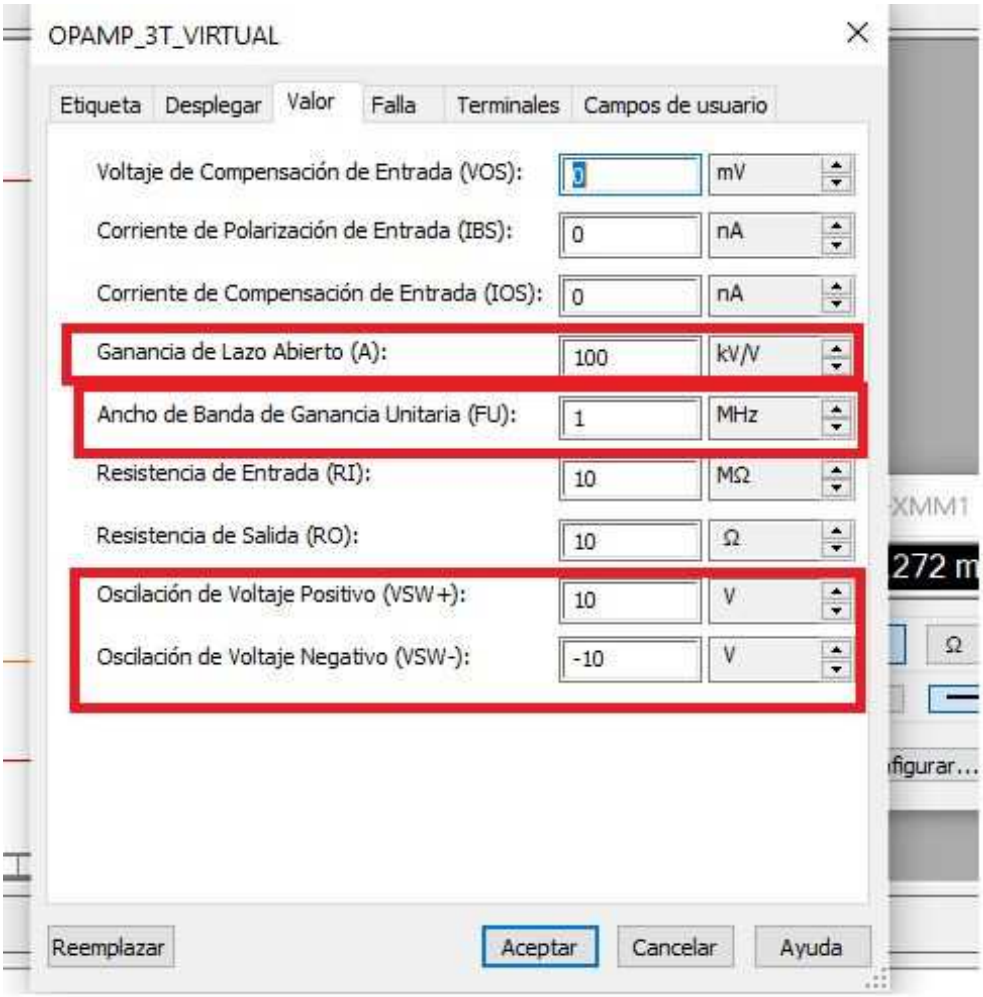

Figure 8. Configuration of OpAmp to behave similar to LM324.

The values displayed by the simulator confirm the design parameters. A voltage of about 500 mV is applied to each resistor, and the current drawn by the voltage divider circuit is 2 mA. Under these conditions, each of the eight LEDs is expected to light according to 5 V voltage increments.

Consequently, according to the voltage levels expected as the maximum in the audio input signal, it is possible to define the required comparison voltages according to the resolution sought in the VU meter design. A large number of small LEDs arranged in line can provide a lot of information in real-time about the behavior of the audio signal, and provide parameters for the volume control of the equipment.

Conclusions

This paper presents the design details of a VU meter for application in sound reproduction systems using several stages of voltage comparators. These voltage comparators are implemented using operational amplifiers without feedback loops and configured with reference voltages derived from the maximum voltage expected in the input audio signal. The maximum value is used as a design parameter to define the input voltage divider circuit configuration (reference for the OpAmps) and output resolution configuration (visualization) of each OpAmp. The visualization is done by a typical LED connected to the output of each OpAmp. These LEDs are protected with a resistor according to the saturation voltage of each OpAmp (based on their supply voltages) and guarantee their correct operation with a series rectifier diode, which also eliminates the need for a dual source for the power supply of the op-amps. Performance tests were performed on an example design, showing the necessary parameters to be defined in the circuit, and verifying its operating point by simulation.

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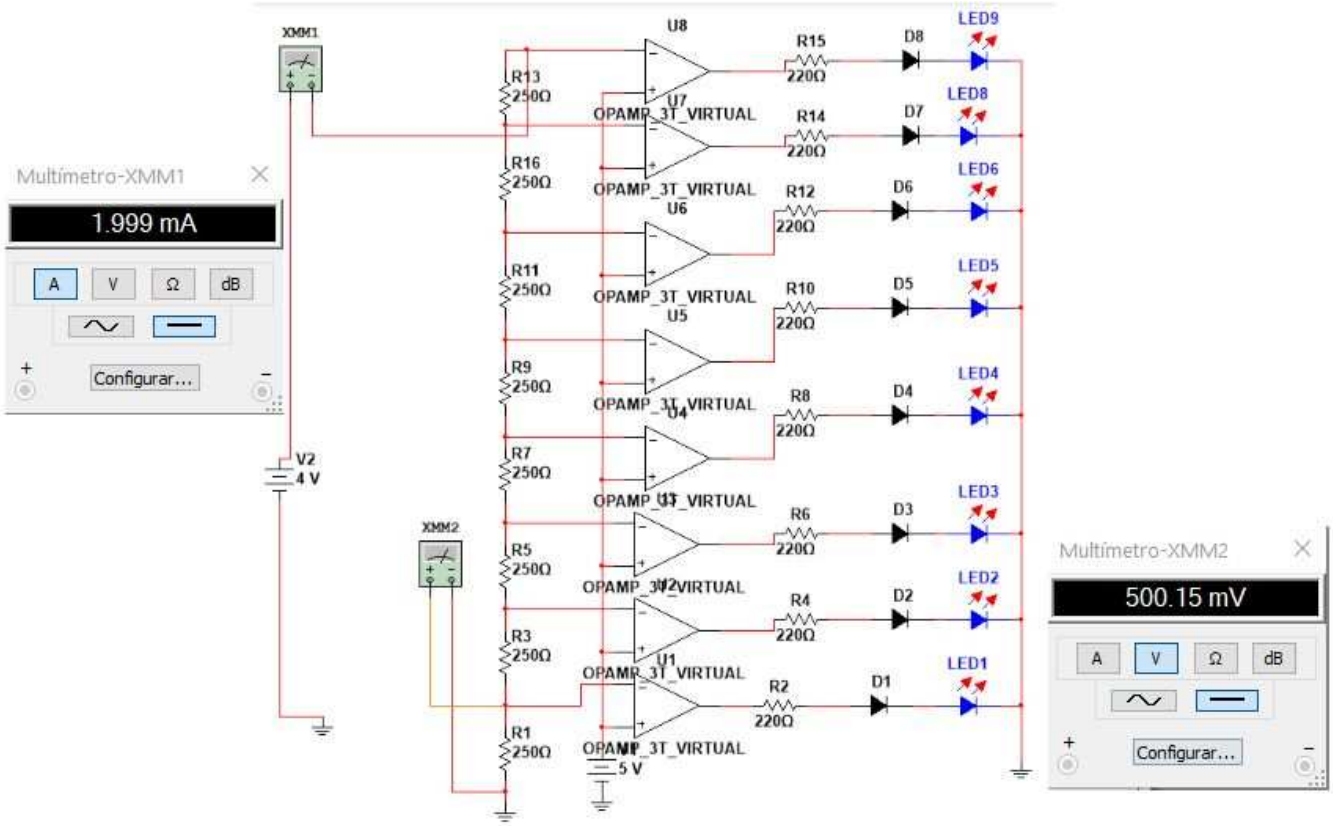

Figure 9. Simulation, voltage meter indicator up to 5 Vdc, in steps of 0.5 Vdc per LED. Current through divider 2 mA.

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Current uses of GIS for civil engineering in Colombia

Usos actuales de los SIG para la ingeniería civil en Colombia

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This document presents and reviews the GIS (Geographic Information System) in Colombia and its possible current uses in civil engineering. Since a model with georeferenced graphic elements (maps) with additional information associated with a database is a very complete design tool, it facilitates engineering analysis to carry out effective construction projects.

Keywords: Analytics, data, engineering, geography, hardware, information, systems, software

Este documento presenta y reseña los SIG (Sistema de Información Geográfica) en Colombia y sus posibles usos actuales en la ingeniería civil. Ya que un modelo con elementos gráficos geo referenciados (mapas) que cuenta con información adicional asociada a una base de datos conforma una herramienta de diseño muy completa, la misma facilita a la ingeniería la realización de análisis con el fin de realizar proyectos constructivos efectivos.

Palabras clave: Análisis, datos, geografía, hardware, información, ingeniería, sistemas, software

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Introduction

Information systems are designed to improve the quality of the points of analysis and relationships that distinguish the territory. However, much of their success is subject to the degree of assimilation of the tools available, and the development of the necessary frameworks to begin to appreciate the field of application of geographic information derived from territorial systems, which constitute the physical-spatial scenario of the interactions produced when evaluating the characteristics of the territory as an information base (DePrekel, Bouali, & Oommen, 2018; Onden, 2018; Palmer, Koumpli, Cole, Gottschalg, & Betts, 2018; Rowden & Aly, 2018).

This article will focus on GIS for Colombia, showing a frame of reference, theoretical review, methodological design, and use (Cantillo, Garces, & Marquez, 2016; Florez, Rincon, Cardona, & Alzate, 2017).

What is a GIS?

Geographic Information Systems (GIS) are methodologies that help us to perform calculations that help us to integrate modeling results, identification, and different geographic features, giving the possibility to generate forecasts, for the corresponding decision making, also helps us with issues related to spatial distribution, capture storage, manipulation, analysis, modeling and presentation of georeferenced data. In addition, GIS can perform high-speed, high-volume numerical calculations, generating accurate and fast communication within and between organizations. It is easily accessible and increases effectiveness and efficiency among groups in a specified location or across multiple locations.

Historical review

The design of maps dates back to Ancient Egypt, where they began to use maps to delineate the land near the Nile River, all this to get the most out of it, in terms of agriculture, is that fact means the beginning of cartographic works. What propitiated the birth of the GIS, the birth of the computer era in the mid-sixties, with that in mind the GIS has sustained a constant evolution, as the emergence of sources that could be used for geographical analysis, in addition to the development of disciplines have contributed to the development of the GIS itself.

The evolution of GIS, comes from a discipline, technology, data, techniques, and formulation, discipline, GIS has achieved a relationship with other scientific disciplines, in technology through GIS software and computer elements has had remarkable growth; with the benefit of the constant acquisition of information increasingly accurate in storage, gives the opportunity for new solutions for management, thanks to the development of new concepts, approaches, theories or branches of knowledge to enhance technical and formulations that ensure better data management.

GIS in Colombia

Technological advances have led to the development of GIS so that a model with georeferenced graphic elements (maps) has additional information associated with a database, which facilitates analysis to produce new results.

The implementation of the systems obeys the relevance of codifying and monitoring, using technological tools, the information on the geographic structure of each region, a framework that implies the revision of the forms stipulated up to now to evaluate and make territorial management.

Contributions to GIS by public companies. The consolidation of geographic information systems as a spatial and territorial database is designed to organize the collection of geographic references available for the time being in analog format. In this regard, the Colombian State assumed the application of information systems in local and regional geography through the Geographic Information System for Land Use Planning (SIG-OTN), under the responsibility of the Agustín Codazzi Geographic Institute (IGAC, 2006), to establish land use and territorial planning processes through the systems (art. 49 of Law 152 of 1994).

Information systems are designed to improve the quality of the points of analysis and relationships that distinguish the territory. However, much of their success is subject to the degree of assimilation of the tools available, and the development of the necessary frameworks to begin to appreciate the field of application of geographic information derived from territorial systems, which constitute the physical-spatial scenario of the interactions produced when evaluating the characteristics of the territory as an information base.

The information systems have as a reference the territorial conditions among those who execute the development plans, as they assume parameters of state and institutional coordination. Thus, the generation of information that permanently assembles the physical-spatial space, allows clarifying the media composition to which planning and projects have been subjected, blurred from the logical order foreseen by the spatial and geographical conditions, which directly constitute the road map required to evaluate the territorial parameters.

The interest in establishing the correlation criteria between the stipulations of the ordinance with the planning based on the information systems is just beginning. It is still in the stage of transferring cartography and analog maps to the digital system, and some pilot programs and tests are being developed in different areas of the country to articulate the initiative to the territorial conditions, exercises in which

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the perception of the inhabitants regarding the geographic image of the territory has played a fundamental role.

The Geographic Information System for Territorial Planning - GIS-OT is one of the results, to date, of an International Cooperation Agreement, signed between the Colombian Government and the Swedish International Development Agency - SIDA, which seeks to facilitate efficient and timely decision making by the authorities and bodies of the National Planning System (President, ministers, governors, mayors, their government teams, Congress, departmental assemblies, municipal councils, and national and territorial planning councils, among others), in support of better territorial public management, within the framework of the Colombian Spatial Data Infrastructure - ICDE.

The GIS-OT has been developed with the active participation of national and territorial entities such as the Colombian Federation of Municipalities, the Presidential Agency for Social Action and International Cooperation, the National Administrative Department of Statistics - DANE, the National Planning Department - DNP, the Ministries of Environment, Housing and Territorial Development, Agriculture and Rural Development, Education, Transportation, Culture, Social Protection, IDEAM, INGEOMINAS, the Governors of Nariño, Valle del Cauca and Cauca, among others; as well as the Agustín Codazzi Geographic Institute, IGAC, which is in charge of technological development and facilitating inter-institutional participation.

From the beginning, the guiding principles of the methodology for the construction of results were defined, as well as an operational structure to achieve them, composed of a Management Group (directors, deputy directors, and managers of 14 entities), execution, and technical coordination group (led by the IGAC, with the support of delegates from the participating national institutions) and a reference group (national and territorial entities).

Among the guiding principles, the collective construction of knowledge and the generation of useful and timely results in the agenda of the National Planning System stand out. Consistent with the above, the Rational Unified Processes -RUP method was proposed and used, which is an iterative and incremental process based on the evolution of executable prototypes; in each iteration, the system gains in development and facilities; which has favored not only the construction of results but also the appropriation, institutional learning, and feedback from all entities.

With the application of this participatory and incremental methodology, the variables to be contained in the system were prioritized, the conceptual model was designed and the necessary documentation was prepared to support the development of the Geographic Information System.

Contributions to GIS by private companies. Most private companies use the GIS developed by public agencies that have generated large volumes of information for their projects, which represents a reduction in costs by allowing its reuse. This is not a definitive solution, because before being useful for an application other than the one for which it was designed, such information must be reworked by the companies, which has allowed the development of GIS complements.

GIS in private companies has also been extended to distribution, planning, logistics, and marketing activities.

On the one hand, the tools they provide make it possible to locate customers, competitors, points of sale, and, in general, any type of information that can effectively assist in a decision-making process. These operations, as well as defining a sales territory, opening or closing a branch, or placing static advertising are decisions with a clear geographical component.

In addition, vendors have brought to market low-cost, easy-to-use systems designed for less complex needs. The power of desktop platforms and the emergence of systems that overcome the limitations of DOS make it possible to use GIS without barriers.

Colombian companies are already aware that the conditions of user-friendliness, cost reduction, and openness of applications are an option to improve their productivity and competitiveness.

Elements of a GIS

All elements of a GIS are important, geographic information systems depend on five main elements, without which they could not function.

Data. These are the raw material to be able to work with GIS, they are the basis of all the knowledge that can be obtained, these data can be obtained in different ways, through GPS, aerial photographs, files obtained in AutoCAD, Excel, and other types of geographic sources. With all this data you can make the different relevant decisions that are necessary to obtain better results.

Software. Among the most important tools are the following.

- **ArcGIS.** ArcGIS is a set of software products, which allows to analyze, to analyze, to treat, to publish geographic information; using different applications, this software is developed by ESRI.
- **OS Geo.** This is free software developed by the Open Source Geospatial Foundation, this is a non-governmental organization, although it does not focus on software development, its mission is to provide support for geospatial technologies, which can

be used to access GIS, although it is not as powerful as ArcGIS.

• **QGIS.** It is another type of geographic information software, which is developed by OS Geo, it is free software that is available in different types of platforms, such as Linux, Windows, or Mac OS.

Hardware. This is necessary because to use the software we need hardware, of course, depending on the capacity of the hardware, so will be the use of the software.

Persons. To be able to analyze the data obtained, it is necessary to have a staff, although several technological tools help us in these processes, it is always necessary to have a physical staff, for this task several professionals are needed, within this range two different types are needed:

• **GIS Technician/Analyst.** In charge of performing geographic analysis and obtaining results depending on the field of research.

• **GIS Programmer.** In charge of developing web applications and functional desktop GIS parts.

Of course, with the frequent growth of GIS, there is always a need for other types of GIS professionals such as managers, administrators, directors; always taking into account the needs of the projects.

Processes. Processes are developed to optimize the integration of data effectively and appropriately, for these you need software and hardware, you also need staff to use the new technologies. You must always have a good organizational model on which to work.

What is the importance of GIS in Colombia?

Its importance depends on the planning of a specific project in a geographic space, being the GIS an active actor in the decision-making process, which helps to determine the characteristics of the territory.

GIS in the field of civil engineering is quite relevant. In Colombia the GIS is a new tool, for this reason when solving the question we recognize the difficulties that arise in the generation of mechanisms that facilitate its introduction as a tool by the staff that operates, like the one that is responsible for making decisions; in addition, there are problems of availability of reliable data that is obtained from the local authority. Regional and National are those involved in land use planning, as such an influential factor, if we want to make progress in the use of GIS.

On the part of the state the use of the GIS, in this case, the municipalities, have used the application, in the fulfillment of the territorial management plans, the problem lies in that this information is not consulted, it is not updated with the information, knowing that with the application daily information is generated, this turns the GIS application, a product that is obtained by hiring external personnel turning it into an element of work, and its importance is left aside, as an active actor in the diagnosis and at the time of decision making in front of pertinent planning.

The GIS facilitates the review of the gap between desired and current conditions, as they allow us to move from a general vision, to the particular with a degree of detail required by the user, in Colombia it is necessary to use the application from a simple but reliable basis because it is an excellent start of the application, to be available to any municipality, being collected daily information, which is easily organized, analyzed, promoting good planning decisions, to ensure that familiarity and experience with the application are reached.

For the above mentioned, the use of GIS applications in Colombia, as an active tool, thanks to being an application in planning and subsequent decision making, in the territorial organization, it is necessary to know their current uses of geographic information systems in Colombia, to recognize and see how they are being used and how to ensure their greatest potential when using them.

The triumph and development that GIS has had throughout history are mainly due to the development of technology, they are born of a simple problem, the need for geographic information, and the ease of obtaining it.

It all began in the ’60s with the work of John K. Wright, in the American Geographic Society, Elements of Cartography. With works such as John’s, this field is expanding until it reaches a level where a system can be proposed in mature computer science.

Waldo Tobler developed the first computational system or tool in 1959 with MIMO (map-in map-out). It was he who proposed the systems for obtaining databases, coding, analysis, and tools necessary for their organization, it was Waldo Tobler who developed the main elements that make up the GIS databases.

The official birth of GIS occurred in Canada in the early ’60s, with the system called CGIS (Canadian Geographical Information Systems), sponsored by the Federal Department of Energy and Resources and developed by Roger Tomlinson who is called the father of GIS, although there was already some development in geographic information technologies Tomlinson is considered a pioneer in his field.

The development of new technologies is a really important step for GIS, what matters for these systems is the encoding and storage of geographic information. Guy Morton made an important contribution with the development of his Morton Matrix, which overcame the deficiencies of the equipment of that time, the most important deficiency overcome was the lack of storage units with random access capacity.

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SYMAP was an application developed to allow the input of information in the form of points, lines, and areas. This software was developed at Harvard Laboratory, this application drove the development of a new generation of cartography and the evolution of these systems to more advanced ones.

GIS platform

There are currently different platforms, chosen depending on the activity and purpose, and even two or more can be used for the same activity.

With the development of free software in the last years, more and better products have been appearing that rival in power and versatility with the most known products with payment license and of privative character. The use of free software allows one not to depend on a software license to be able to continue expanding and deepening the knowledge and development of these systems.

The following is a list of the most commonly used GIS programs.

ArcGIS. ArcGIS is non-free software developed by Esri. The two main desktop applications for GIS professionals are ArcMap and ArcGIS Pro, both of which are part of ArcGIS for Desktop. Each application has unique features to suit your needs. You can create everything from simple web maps to complex analytical models.

QGIS. QGIS is open-source software licensed under the GNU - General Public License. QGIS is an official project of the Open Source Geospatial Foundation (OSGeo). It is available for Linux, Unix, Mac OSX, Windows, and Android and supports numerous vector, raster, and database data formats and functionalities.

gvSIG. gvSIG is easy to use, interoperable, and used by thousands of users around the world. gvSIG Desktop works with a variety of formats, vector and raster, files, databases, and remote services, having available all kinds of tools to analyze and manage geographic information. gvSIG Desktop is free software, with GNU/GPL license, which allows its free use, distribution, study, and improvement.

GRASS GIS. GRASS GIS, more commonly known as GRASS, is a free and open-source GIS software used for geospatial data management and analysis, image processing, graphics and map production, spatial modeling, and visualization. GRASS GIS is currently used in academic and commercial environments worldwide, as well as by many government agencies and environmental consulting firms.

OpenJUMP. OpenJUMP is free GIS software that allows visualizing layers and spatial queries performed on a PostgreSQL/PostGIS database.

SAGA GIS. SAGA is the abbreviation for System for Automated Geoscientific Analyses, an open-source and Free GIS, with an interesting set of scientific algorithms for working with vector and raster data. A very powerful and robust alternative to the most popular GIS mentioned above.

LAStools. It is a collection of tools for LiDAR data processing.

CARTO. CARTO es una herramienta para la creación y publicación de mapas en la nube. Las funcionalidades son muy amplias, y están diseñadas para distintos perfiles de usuarios. Desde aquellos sin experiencia que únicamente quieran visualizar y analizar un conjunto de datos geográficos, a aquellos que quieran crear aplicaciones y visualizaciones complejas, o realizar análisis profundos de los datos con que trabajen.

Fusion Tables. Google Fusion Tables is a Google web service for managing data stored in tables that can be consulted, shared, and edited by any user over the Internet. Fusion Tables allows definition access permissions to the tables and offer an environment for data visualization through graphs, scatter diagrams, and timelines. Also through maps based on Google Maps.

Mapbox. Mapbox is an online platform that allows the creation of cartographic reference bases, as well as the development of web maps and mobile applications for the consultation of georeferenced information.

ArcGIS Online. ArcGIS Online allows you to use, create and share maps, scenes, applications, layers, analysis, and data. It provides access to a databank and creates interactive web maps. As ArcGIS Online is part of the ArcGIS system, it can be used to extend the capabilities of the different products that make up the system (ArcGIS Desktop, ArcGIS Enterprise, ArcGIS Web APIs).

PostgreSQL. PostgreSQL is a freely distributed relational database management system (DBMS) under the BSD license. Among its potentialities, it is worth mentioning: the high level of accessibility for any type of user; the existence of an extension or module (PostGIS) that provides geographic capabilities to the databases; the high quality of the product, being the most advanced open-source DBMS.

PostGIS. PostGIS is the spatial extension for PostgreSQL that allows the storage of geographic data. It adds functionality to spatial objects that allows SQL queries.

SpatiaLite. SpatiaLite is an SQLite database engine to which spatial functions have been added. SQLite is a simple but robust database management system, easy to use, and lightweight. Each database is simply a file.

OpenLayers. OpenLayers is an open-source API for displaying interactive maps on the web.

Leaflet. It is an open-source API for displaying interactive maps on the web.

GeoServer. GeoServer is an open-source web server that allows serving maps and data of different formats for web applications.

GeoWebCache. GeoWebCache es una aplicación web basada en Java que sirve para mejorar el rendimiento de las teselas de mapas procedentes de distintas fuentes como geoservicios OGC (WMS).

GeoExplorer. GeoExplorer is an application, based on GeoExt and OpenLayers) allows the symbolization and creation of online maps. It allows to easily assemble maps from GeoServer or any OGC geoservice (WMS) and integrate with maps such as Google Maps or OpenStreetMap.

GeoNode. GeoNode is a web application and platform for developing Geographic Information Systems and implementing Spatial Data Infrastructures. It is an open-source project of OSGeo.

GeoNetwork. GeoNetwork is a catalog for managing geospatial data metadata. It is an open-source project of OSGeo.

iD. The iD editor is the de facto browser-based OpenStreetMap editor. iD is easy and fast to use and allows mapping from different data sources such as satellite and aerial imagery, GPS, or Field Papers.

JOSM. It is a free desktop software programmed in Java for editing data in the OpenStreetMap project. It has numerous advanced features. Some of the most notable features of JOSM are GPX file import, working with satellite images or orthophotography through standardized protocols (WMS, TMS, and WMTS), support for multiple cartographic projections, information layer management, relationship editing, error validation, filters, and rendering styles among others.

GIS structure

The success of a GIS depends on the structure of its implementation since these are complex tasks. But to organize and coordinate in an effective and adequate way all the elements of a GIS must be a basic task, in general, each of the elements must be considered individually and its relation with the others, the organization, and formation of a GIS is conformed by the following structure.

Data. The data are the fundamental basis of a GIS, in general, all the data are important, but at the time of using them it is necessary to have a selection of each one of them, that is why to be able to have access to them in an effective way it is necessary to create a database, that not only is modifiable by him, or the designers but also by the users, for them it is necessary to have good communication with the person who is going to make use of these data and to obtain the information that helps to optimize the database.

First, data must be collected, that is to say, information must be obtained from already structured databases such as those of private suppliers, government agencies, or any other entity that has them, especially to optimize the information that is acquired and create new information from it, that is to say, to optimize the database.

If data collection is taken as a percentage of the process, it could be said that it is only 50%, if a new database is created from those already obtained, we will have a large number of similarities in the information obtained and even more if all the information comes from a single database, This does not help the search work of the users, that is to say, not all will be served by the same information, therefore, it is necessary to look for particular characteristics and separate the information, so that when you want to carry out an investigation you do not get too much-unwanted information and that does not offer something to the project you want to carry out.

In general, some data can cover regions with too much extension and only a small sector is sought, in those cases, the information must be delimited, and on the contrary, very little information can be obtained from a site of great extension, for that reason, it is necessary to try to obtain more information in order to obtain a more updated and efficient database.

Persons.

Software.

Hardware.

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GIS functionality

When analyzing the functionality of GIS, it should be taken into account that, being a specialized program, it has a high degree of complexity, for this, it is useful to divide the topic into subtopics, to make a better description of the most representative functions, of these we will talk about: technology, data, methods, organizations, and network. In addition, it is necessary to talk about functions such as Information Entry, Storage, Management, Spatial Analysis, and Output or Graphical and Cartographic Representation of Information.

Network. The network is the main element of a GIS because it generates advantages in the field by allowing the visualization, consultation, and analysis of spatial information without the need to download large amounts of data.

Technology. It is structured by software and hardware. In the case of hardware, the user can perform different actions of input and output of information as in the case of file transfer, output devices such as printers, monitors, etc., regarding the software, it acts as a logical entity that organizes, directs and gives consistency to the whole system.

Data. Data are the part using which reality is represented, with which it is searched in the situations, for the realization of specific application, since data are restatements of facts and represent a necessary pillar for knowledge.

Methods. The methods aim to establish the structure of a GIS, while at the same time seeking to support decision making to achieve project success.

Organization. GIS only makes sense in the context of an organization, as it establishes procedures, reporting lines, control points, and other mechanisms to ensure the budget, these factors being paramount to the work, ensures the need for the organization.

Functions for data entry

They are those that allow the introduction, edition, and visualization of geographic data, its importance resides in issues where spatial information is very scarce. Where the process of obtaining it can be tedious and very expensive. The processes in the information input function usually absorb between 50% and 70% of the budget for the implementation of a GIS and also require large resources in the modification of the geometric characteristics of the orientations, position, shape, and correction of inconsistent data.

Storage functions

Once the geographic information has been captured, and a large amount of data has been collected, the storage function appears in this process, where, in addition to the computer hard disk, it is necessary to transfer the information to other computers or electronic devices, given the importance of having backup copies.

Management functions

This function extracts from the GIS database the proportions of spatial information that are of interest at the time, thus the management function is responsible for allowing the independence of the physical organization (database) from the logical organization of the data (programs that manage the data), to achieve control of storage and retrieval.

Spatial analysis functions

They are those that are attributed the value to the geographic data, to expose us to geographic data because without it we cannot perceive, know and understand the spatial operations, besides being a useful tool to plan better and efficient work. Among its capabilities are the query operation, perimeters, areas, overlapping layers of information, reclassification of data.

Output functions or graphical and cartographic representation of information

They are those that allow the transfer of data, maps, this we perform the representation of stored data that allow visualizing the information according to the required need, for this case depends on how it is done, in this sense should be careful in the way in which it is done, be aware of the result they are looking for.

Application of GIS for civil engineering in Colombia

GIS applied to geology

Currently in Colombia, the national geological information is managed by the state government through the Ministry of Mines with the Colombian Geological Service. The "Geoportal of the Colombian Geological Service" was developed for the visualization of the geological characteristics of the national territory.

The purpose of this Geoportal is to present to users the information generated by Geo Basic Sciences, Mineral Resources, Geo threats, Nuclear Affairs, Laboratories, and Information Management, in compliance with Law 1712 of 2014 "Law of transparency and the right of access to public information" and according to articles 11 literal J and K, article 12, article 13 and article 14.

The information is stored in a corporate geodatabase managed by the Oracle database engine, ESRI Suite tools, and customized web applications using ESRI Geoportal Server (Open Source Software).

Through this platform, the information is dynamically managed and available to the user online. It also complies with open source standards such as WMS (Web Map Service), WFS (Web Feature Service), WCS (Web Coverage Service), and REST (Representational State Transfer) services.

The purpose of this information is to establish initial conditions of the territory for the realization of public and/or private projects. Among the information found in this Geoportal are:

- Basic geosciences
- Mineral Resources
- Geo hazards
- State geological mapping
- Petroleum Information
- Volcanic hazards
- Geophomodynamics
- Geochemical Anomalies and Geochemical Potential
- Geological Atlas Colombia
- GNSS Stations SGC 2014
- Maximum Observed Intensity
- Carboniferous Potential Map Colombia

GIS applied to mobility and transportation

As mentioned repeatedly in this article, GIS allows us to extract the necessary information in a more effective way reducing search times and providing the relevant information for further analysis, in mobility, they are widely used, they allow us to know the state of the roads and also to know the traffic density of a given road.

Several urban transportation companies use these systems to optimize their times and provide a better service, such as Transmilenio, Mio, Medellin subway, etc., in general, these companies filter the information obtained, although this is already filtered in a useful way it is not perfect since these systems are still under development.

For a road system, it is necessary to make a previous analysis with a GIS, at the present time the use of these systems is indispensable, more in cities with a great density of traffic like Cali, Medellín, or Bogotá, since most of the roads of these have been thought for the transit of particular vehicles, and the massive systems of transport have been left to aside, in the last years it has changed something of that thought, but due to the errors committed with the type of design of the roads the consequences have been terrible, with help of the GIS some of these problems can be solved.

The GIS provide us with different types of information such as the location, the condition of the terrain, the trend, the possibility of developing roads from one place to another, and models, the GIS have a lot of advantages, within these are the cartographic manipulations which allow us to handle the information obtained in such a way that we could make an estimate of the work and the amount of material that needs to be moved. We also have the ability to compare the information in a relevant and effective way, in order to make a more accurate decision making.

For the respective analysis of a road network, a Geodatabase must be created, which is a database containing traffic density, geological risks, hydraulic network, cadastre, surface types, slopes, and other information necessary to develop a well-structured road in a way that does not affect the environment and that solves the mobility problems that arise in the sector. GIS is the main solution to the geomorphological problems that arise in mobility and ease of access to the different terrains of our country.

GIS applied to urban planning

In order to talk about GIS applied to urban planning is necessary to know the agency responsible for urban planning in Colombia is the National Planning Department (DNP), of which among its functions is to provide technical support to public entities of national and territorial order, in addition to generating plans for a short, medium and long term, where investment is prioritized. DNP is in charge of monitoring projects with an emphasis on regional convergence, territorial planning, and articulation between levels of government and sources of resources in the territories, also in functions is the programming of the budget of the different sources of investment resources, taking into account government priorities and development objectives of the country, likewise participate directly in the evaluation of private investment projects, national or foreign in which the government is part.

As illustrated, GIS is a fundamental tool for this agency, because it generates opportunities for better information management, accurate location in the region, in the search for investment and better territorial control, in addition from the GIS decisions can be made, facing the design and methodologies of urban socioeconomic stratification and population centers, To achieve this type of decision making, it is necessary to have protocols for the georeferencing of data (which are considered metadata for the immense amount of information that is acquired daily), which at the same time provide us with digital cartographic products that serve as support for the operational processes of data collection in research.

Strengthening the use of geographic information systems provides us with relevant results of public interest in national, regional, and local development, ensuring access, use, and security of national geographic information, within the framework of social, demographic, and economic policies.

The importance of GIS lies in the convenience of having geospatial information available, where processes, procedures, policies, strategies, and norms can be articulated to standardize and geographically complement economic,

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social, and environmental issues, for a closer public evaluation.

Colombia currently manages the SIGOT platform for national-territorial planning and management. The SIG-OT (Geographic Information System for National Planning and Land Management) is a tool whose main objective is to contribute to efficient and timely decision making, supporting the actors -authorities and agencies- in the planning system at national, regional, and local levels, with georeferenced political-administrative, socio-economic and environmental information that supports development management.

The SIG-OT is framed within the principles, objectives, and strategies postulated by the Colombian Spatial Data Infrastructure - ICDE. It is the result of a technical cooperation project with the Swedish International Development Agency (ASDI). The project has the support of Swedesurvey, the Swedish counterpart of IGAC, executor of the cooperation. IGAC is technically responsible for and facilitates the inter-institutional management of the project.

The objective of the SIG-OT is to facilitate mayors, governors, and those responsible for national and sectoral planning, the elaboration of diagnoses, and the follow-up, evaluation, and control of their respective development plans. It contributes to the definition of strategies for the management of their territories and to the targeting of goals in the territorial management plans. It helps to generate a culture in the use of geographic information as a basis for decision-making.

Governors, planners, and society, in general, can make use of the SIG-OT through the IGAC's web page, where a user-friendly and free-access portal has been set up. The only requirement is Internet access. On the portal it is possible to build, display and print national and departmental maps of various topics; prepare executive reports on the status of a topic by department or throughout the country, and consult the technical data sheets of the maps (Metadata).

These maps are used, at the national level, to evaluate territorial imbalances in terms of quality or coverage of education, and to define policies and strategies with a territorial approach. At the departmental level, they are used to evaluate imbalances and compare with the allocation of territorial public spending to establish strategies and additional measures to rationalize investment. And at the municipal level, they are used to compare with the context (departmental or regional) and define priorities and goals; they allow temporal comparisons to analyze change or stagnation to better orient actions.

GIS applied to the environment

Institutionally, environmental information is managed by the Ministry of the Environment through the SIAC platform. The Colombian Environmental Information System (SIAC) is the integrated set of actors, policies, processes, and technologies involved in the management of environmental information in the country, to facilitate the generation of knowledge, decision making, education, and social participation for sustainable development.

SIAC is based on a process of interinstitutional, intersectoral and interdisciplinary coordination, led by the Ministry of Environment and Sustainable Development (MADS) and the Environmental Research Institutes: Instituto de Hidrología, Meteorología y Estudios Ambientales (IDEAM), Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH), Instituto de Investigaciones Marinas y Costeras (INVEMAR), Instituto Amazónico de Investigaciones Científicas (SINCHI) and Instituto de Investigaciones Ambientales del Pacífico (IIAP), as well as the Special Administrative Units, the National Parks System and the Autoridad Nacional de Licencias Ambientales - ANLA. The Ministry of Environment and Sustainable Development, through Resolution 1484 of October 31, 2013 regulates the constitution of the Steering Committee of the Environmental Information System for Colombia SIAC. Advisory body of the ministry in charge of proposing policies and strategic guidelines for the management of the country's official environmental information.

SIAC member institutions are working to develop instruments and tools to promote the use and full and open exchange of data and information for research, environmental education, public policy design, and corporate sustainability strategies.

Among the tools designed is the SIAC Viewer version 1.0. The SIAC viewer is a platform that centralizes the official geographic information of the different institutions involved in the environmental sector for its visualization, management, and analysis. This tool is aimed at groups of professionals, institutions, companies or organizations and, in general, citizens who have the interest and need to consult, process, and analyze environmental data associated with different variables, in such a way that it serves as a support for planning, decision making on the territory, evaluation of environmental impacts, programming of productive activities, identification of trends, generation of forecasts and prediction of environmental alerts.

The SIAC geographic viewer contains the following information on the national territory.

Water. Supply, demand, water quality, and vulnerability.

Soil. Threats, forest reserve area, transformed areas, land cover change, forest degradation, species distribution, the legal status of the territory, strata of anthropic intervention, wetlands, forest map, ecosystem maps, land cover maps, glacier monitors, conservation

portfolio, forest cover change, national system of protected areas, environmental zoning.

Weather. Hazards, precipitation, temperature, vulnerability.

Environmental licensing. Energy, mining, infrastructure, hydrocarbons.

Conclusions

This article is a study and analysis of the importance of Geographic Information Systems (GIS) at the civil engineering level, particularly in the context of Colombia. First, the basic characteristics and functionalities of GIS systems are defined, and then an analysis is made of what they have been in Colombia, their initial intention, and their current operation from the perspective of the existing tools and their uses. The institutions in charge of their use and maintenance are also detailed.

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Space building case

Caso edificio Space

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The Space building was a residential complex located in the city of Medellín (Colombia), which was divided into six stages or towers. In the last stage of the project, tower six suffered a structural failure that caused its collapse, which led to the demolition of the other towers. The main issues discussed are related to the design of structures, columns, beams, and loads that a structure can withstand given the terrain and the materials used for construction. In addition, the study carried out by the Universidad de Los Andes, which was the main source of information in the investigation of the collapse and its aftermath, will be presented. This article will collect and show information on this case in the areas directly related to civil engineering and what happened to those involved in the project.

Keywords: Beams, civil engineering, columns, structural design, structural loads

El edificio Space fue un conjunto residencial ubicado en la ciudad de Medellín (Colombia), el cual se dividía en seis etapas o torres. En la última etapa del proyecto, la torres seis, sufrió una falla estructural que produjo el colapso de esta, y esto llevó a la demolición de las demás torres. Los problemas principales que se trataron están relacionados con el diseño de estructuras, columnas, vigas y cargas que puede soportar una estructura dadas las situaciones del terreno y los materiales utilizados para la construcción. Además, se dará a conocer el estudio realizado por la Universidad de Los Andes la cual fue la principal fuente de información en la investigación del colapso y posteriormente a este. El presente artículo recolectará y mostrará información de este caso en los ámbitos ligados directamente a la ingeniería civil y lo ocurrido con los implicados en el proyecto.

Palabras clave: Cargas estructurales, columnas, diseño estructural, ingeniería civil, vigas

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Introduction

The function of the bone system in the human body is to support, to keep the body rigid internally and externally; the same happens with buildings, these must-have their systems that make them rigid to withstand any type of internal and external force, therefore, the bone system of a building consists mainly of columns and beams that provide the necessary support for it to stand and support its weight. If a component of this system were to fail in both cases, the same thing would happen, it would lose support and stiffness, which is why the good design of column and beam proportions is very important (Fig. 1).

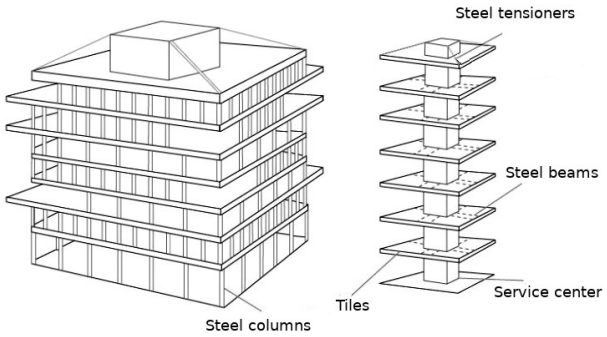

Figure 1. General structure (Alli, 2019).

Taking as a reference the concept given by the engineer López (López, 2005) which defines structures as "*the structure is and has always been an essential component of architecture and civil engineering, and it is precisely the engineer and the architect who, during the design process, must create and invent the structure and give it correct proportions*".

Bone structure design

Structural design is the creative process where the structural system or skeleton of the building is carried out, in addition to the calculations of the most viable materials to carry out the construction (table 1). ARQHYS magazine defines it as follows: "*structural design is one of the areas where civil engineering is developed and is carried out based on the potential that a material can offer, as well as the natural characteristics that make it specific, its low cost, and its mechanical properties. A failure in the structure can occur when the rigid part and the plastic part of the element is in excess, however, if a good level of these two is maintained it is likely to have optimum performance*" (Arohys, 2018).

Table 1
Conception of a structure (Arohys, 2018).

Structuring	When required, a preliminary structuring will be made proposing the location and dimensions of the structural elements that will allow refining an architectural project.
Analysis	It provides us with the displacements and mechanical elements of the members of the structure.
Design	Based on the mechanical elements of the analysis, the dimensions and reinforcement of the members of the structure are provided.
Drawing	With the above data, the structural drawings are drawn.
Calculation memory	A descriptive calculation report of the structure is made, mentioning dead and live loads used, as well as design examples.

Parts of the building's skeletal system

Concerning the bone systems of the building, it is important to talk about the most important elements, called columns and beams.

Columns are those that help to hold up the mezzanine or other types of elements. The column is the vertical structural element used to support the load of the building (Figs. 2 and 3). It is widely used in architecture because of the freedom it provides to distribute spaces while fulfilling the function of supporting the weight of the construction; it is a fundamental element in the scheme of a structure and the proper selection of its size, shape, spacing, and composition. They have a direct influence on its load-bearing capacity (Gálves, 2017).

The beams are the ones that generate a horizontal load force by supporting the weight and tension of the plates, the dead and live loads of the building (Fig. 4).

The engineers at Arcus Global (construction company) define beams as: "*The beam is the construction element on which the support of all the structures we see every day depends. We must understand that beams are not only intended to support pressure and weight, but also to do bending and tension, it is a horizontal structure that can hold load between two supports without creating lateral thrust, they are ideal for bridges*" (Arcus, 2018).

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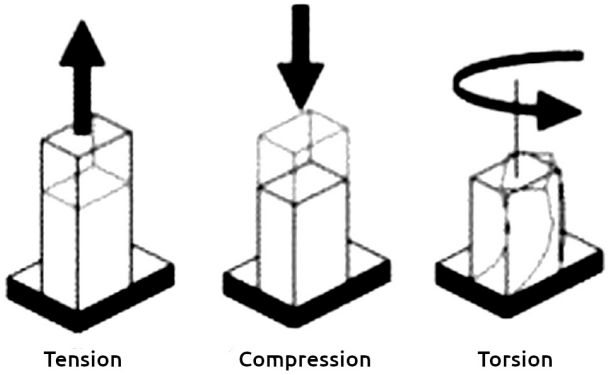

Figure 2. Forces on a column (part A) (Bautista, 2019).

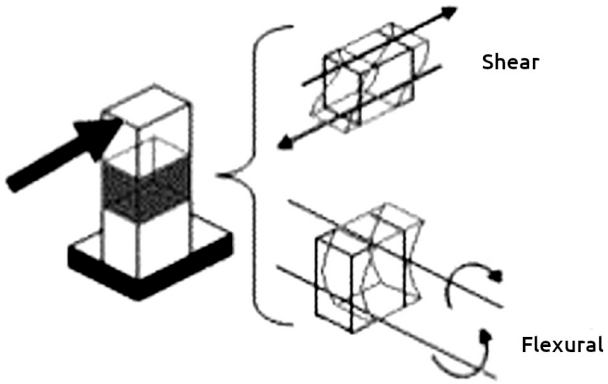

Figure 3. Forces on a column (part B) (Bautista, 2019).

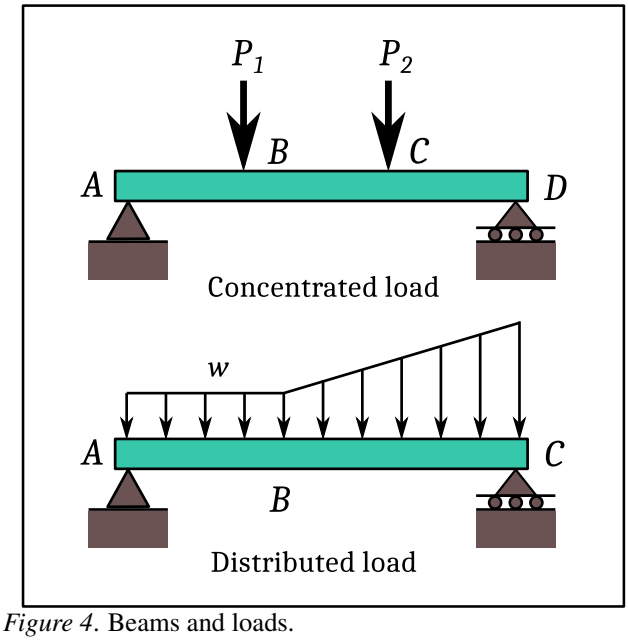

Figure 4. Beams and loads.

Loads to be supported

There are three types of loads in construction (table 2).

Table 2
Types of loads in construction (Aguado, 1994).

Live loads	They vary in intensity over time due to the use or exposure of the structure (human traffic, temperature changes, machinery, snow, or hail accumulation).
Dead loads	They act continuously and without significant changes (the self-weight of the structure, floor and ceiling finishes, columns, beams, and slabs, etc.).
Accidental loads	They act unexpectedly during indefinite periods (wind gusts, earthquakes).

Each component mentioned in the table above must resist different types of loads that are fundamental to take into account when designing beams and columns, since the weight of the structure, in general, must be taken into account so that no collapse of the structure is caused.

When carrying out a construction project it is very important to take into account the loads that it must support mainly from the design, with the intention that the building in question supports its weight and the other loads that are applied on the building. Taking the above into account, the engineer must ensure that the materials to be used can meet all the parameters of the project, either the weight of the cement used in the walls and slabs, as well as the thickness and type of rebar in the beams, columns, and slabs of the entire building, being this part of the dead loads that are the main part of the beginning of the project.

Structural walls

Walls have great importance in the design of loads in the structure. Walls are those construction elements with a parallelepiped shape, in which the dimensions of length and height dominate over that of thickness, which primarily fulfills resistant structural missions (transmitting loads of the floors and roofs) and those required insulation functions (phonic and hygrothermal) as well as adequate fire resistance (Diéguez, 2002).

According to their design and mission, they are divided into two main categories (Fig. 5).

Load-bearing walls. If they are not only self-supporting but are also subjected to external loads and thrusts.

Dividing walls. When they have compartmentalization missions and are fundamentally subjected to the action

of their weight and without other mechanical actions than self-supporting.

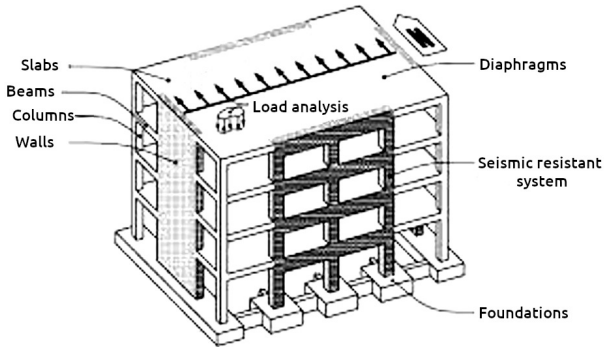

Figure 5. Structural design of a building (Poston, 2019).

Wall symmetry

To verify the distribution of the symmetry of the walls, first, the respective distributions of the walls must be made in the sketch of the plan to be presented, it should be noted that the lengths of the walls that go in the same direction must be similar for greater torsional rigidity in the building. The symmetry can be verified with Eq. 1.

$$\left| \frac{\left[\frac{\sum(L_{mi}b)}{\sum L_{mi}} - \frac{B}{2} \right]}{B} \right| \leq 0.15 \qquad (1)$$

Eq. 1 tells us that there is a margin or area of error allowed to consider the house as symmetrical, this margin tells us that our real axis of symmetry, calculated for the proposed design must have a maximum of 15% offset from the theoretical axis to the real axis of the house, which would be half the length of the house, expressed with the letter B (Agudelo, 2019).

Footings

The footing is a shallow foundation normally used in soils with medium or high compressive strength, on homogeneous soils (Fig. 6). Its function is to anchor and transmit the stresses generated by a structure to the ground on which it is located. It is located at the base of the structure and is usually found as a concrete prism under the pillars (or columns) of the structure. The division of the footings is detailed in table 3.

A disaster foretold

The Space building in Medellín (Fig. 7) was a project with more than 200 apartments in six stages built on 10,800 square meters by the construction company CDO in the Poblado neighborhood in 2006, which was planned to be built in an area considered unusable by the Mayor's Office of Medellín in the Land Management Plan (POT) (Alvarez,

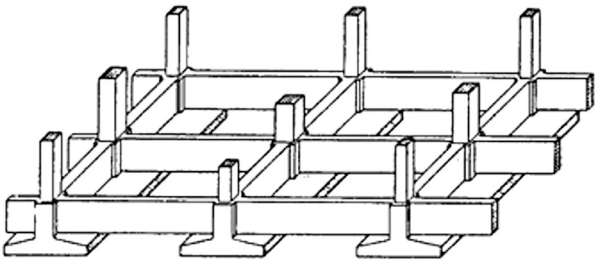

Figure 6. Spread footing in foundation plane (Geotecnia, 2019).

Table 3
Footing types (Arcus, 2017).

Flexible footings	This type of footing supports tensile and compressive forces of the structure.
Deformable or rigid footings	The edge is equal to or less than the maximum flight measured in both directions.
Square footings	They are those with equal sides.
Centered footings	This type of footing is tied or braced with concrete or reinforced concrete braces of a section smaller than the footing.
Rectangular footings	These are footings with unequal sides.
Circular footings	Its main characteristic is its circular shape.

2017). In 2013, the construction phase of Tower 6 and the entire building was completed.

Figure 7. Space building structure design (Suárez, 2019).

Problems in the combined structural system began to become evident in the columns that were the first to fail and the plates began to sag, in addition, cracking was seen

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in many main and dividing walls of Tower 6 (Fig. 8). On Friday morning, October 11, 2013, the inhabitants of the Space Building contacted the Administrative Department of Disaster Risk Management (DAGRD) because a column of Stage 6 had failed (Toro, Yepes, & Castaño, 2016). This entity observed the problems and the structural failure of the column, therefore, decided to evacuate Stage 6 of the Space Building. For which the construction company stated: "*There is no danger for the rest of the building where no structural failure was found*".

Figure 8. Photographs of the columns before collapse (Suárez, 2019).

But a few hours after the press release, on October 12, 2013, at night, Tower 6 collapsed (Redaccion, 2013). According to the study conducted and the conclusions delivered to the Mayor's Office by the Universidad de Los Andes, the collapse of stage 6 was mainly related to the lack of structural capacity of the columns of the Space Building. These, according to the study, were not able to withstand the normal loads to which they were subjected.

The primary cause of the collapse of the SPACE building lies in the lack of structural capacity of the building's main columns to resist the acting loads due to the structure's weight and the imposed service loads (Fig. 9). In particular, the columns of the R-3 and S-3 axes presented acting loads that exceeded their capacities at critical points, which caused them to present structural failure by compression on February 20, 2013, and October 11, 2013, the latter one day before the collapse of the building. The lack of structural capacity is associated with deficiencies in the sizing and design of the main structural elements (columns, beams, and slabs).

There is evidence that the building suffered from internal structural problems and pathologies in the months and days before the collapse which include cracks and crevices in masonry partition walls, excessive vertical deflections in the floor slabs, and structural failures in at least two main columns of the building (Fig. 10) (Buitrago, Callejas, & Moreno, 2018; Toro et al., 2016).

Figure 9. Lack of continuity in structural walls (Suárez, 2019).

Figure 10. Cracks and fissures in dividing walls (Suárez, 2019).

According to the NRS in Title B (loads) a structure must comply with the following requirements (Ingeniería Sísmica, 2010):

- Resistance
- Operation
- Forces caused by imposed deformations
- Analysis

From which the SPACE building did not comply with item A, since the materials used in the plates, columns, and beams were not adequate to support the weight of the building and which was one of the main causes of the collapse of the building, from the above it began to investigate whether the materials used failed, of which engineers warn that in general imported materials that are not of good quality were used in the construction. Particularly with the steel, which is what keeps the beams that support the structure of the entire building standing.

After the collapse of Tower 6, the other towers were demolished because it was concluded that all of them had structural design flaws after studies conducted by the Universidad de Los Andes and the prosecutor's office said: "*the columns were not thick enough to support their weight. In addition, it found that there were 5,500 transgressions to the seismic resistance standard in the entire residential complex*" (Fig. 11).

Figure 11. Demolition of towers 1, 2, 3, 4 and 5 (Mercado, 2019).

To establish the most probable causes of the collapse, the investigators ruled out hypotheses about possible external events such as earthquakes, landslides, explosions or internal fires, and extraordinary overloads on the building, other than those established in the analysis of the structural conditions of the building itself. It was identified that the building presented several pieces of evidence of internal structural problems and pathologies in the months and days before the collapse (table 4) (SCI, 2014).

Table 4
Structural problems identified.

a) Cracks and separations in the internal dividing walls in several of the Stage 6 apartments.
b) Excessive vertical deflections in the mezzanine slabs generated overloads in the masonry partition walls and the need for floor backfilling, and therefore, high overloads to achieve the required levelness for the installation of the floor finishes.
c) Structural failure due to compression in the R3 shaft column at level 5 reported in February 2013.
d) Structural failure by compression in the S3 shaft column at level 4 reported on October 11, 2013.

The analytical evaluations of structural reliability indicate that the probability of failure of the building, in the conditions in which it was found at the end of the deconstruction phase, was close to 100%. It was also found that, had the building's columns been adequately sized following current regulations, the probability of failure of the building's critical column would have been very low (less than 0.1%), even considering the occurrence of the differential settlements recorded.

In the opinion of the specialists and experts of the Universidad de Los Andes, if the structure of the SPACE building had been designed in compliance with all the applicable requirements of Law 400 of 1997 and its Regulatory Decrees (NSR-98), Stage 6 would not have collapsed as it did under the imposed conditions (AIR, 2014).

It could be concluded as a result of the tragedy that if all the structural requirements stipulated in Law 400 of 1997 had been fully complied with, which refers to the standards for seismic-resistant constructions, and which in its first article refers to the minimum criteria and requirements for the design, construction and technical supervision of new buildings, as well as those essential for the recovery of the community after the occurrence of an earthquake, which may be subjected to seismic forces and other forces imposed by nature or use, to be able to withstand them, increase their resistance to the effects they produce, minimize the risk of loss of human lives, and defend as far as possible the heritage of the State and citizens (MinAmbiente, 1997).

The main idea that this law wants to make clear with the above article is that each construction must have compliance with each minimum requirement that is presented in the course of this law, which was not fully implemented in the development of the construction of the Space building, without taking into account the risks that would cause and caused if the building failed, which happened and took the lives of 12 people and left homeless many others who lived in each of the 5 remaining towers that had to collapse.

A building designed according to the requirements established in the standards that regulate seismic-resistant constructions must be able to resist, in addition to the forces imposed by its use, low-intensity tremors without damage, moderate tremors without structural damage, but possibly with some damage to nonstructural elements, and a strong tremor with damage to structural and nonstructural elements, but without collapse. Care in design and construction and technical supervision is fundamental for the seismic resistance of structures and nonstructural elements.

The article also stresses the importance of preventing a collapse from the design of the structure, which must be on a ground that can withstand the conditions to which it will be subjected, and which was the main cause of many people being endangered if the structure fails, as in the SPACE case.

Although this case, unfortunately, served to alert the mayor's office of Medellin since in the El Poblado sector there were also large buildings such as the Continental Tower and Asensi building, which also had serious structural

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failures, these 3 buildings share a similarity which is the construction firm COD, in the next chapter we will discuss legal issues of the officials involved in the construction of the Space building and everything related to the post-collapse of the building.

The effects of an error

Following the consequences of the collapse and demolition of the other towers, an investigation was carried out to find out what happened and to provide a solution to the problem.

In the case of Continental Towers, one of the buildings evacuated shortly after the collapse of the Space tower, according to the specialist Roberto Rochel, professor at Eafit, it is better to demolish it than to repair it (Fig. 12). The fact that not one but several buildings were evacuated to study their structures, both in El Poblado and in other areas of the city, highlights the probable existence of a systemic problem and not a specific one (Mundo, 2013).

Figure 12. Continental Tower photo, October 2018 (Sánchez, 2019).

After the collapse of tower 6 of the Space building in the El Poblado sector in Medellin, to the disbelief of the people of Antioquia, who believed that these towers were made to last until the end of time, the disbelief increased even more, when several buildings were evacuated for possible construction deficiencies and that had been built or were being built by the company CDO as the Continental Tower building which was one of the buildings evacuated a few days after the collapse of Tower 6, The fact that not one but several buildings were evacuated to study their structures, both in El Poblado and in other areas of the city, highlights the probable existence of a systemic problem and not a specific one (Fig. 13). This case helps to demonstrate that people trust in the durability and resistance that a structure may have because of its aesthetics or architectural design, but they do not see the internal part of the structure which was the cause of the collapse that over time became more evident; the damage to the columns, the cracks that were created in the main walls and finally a sudden collapse.

Figure 13. Lot of the Space building after demolition (Sáenz, 2019).

As of today, the COD company has not given any response to the owners of the apartments in the Continental Tower building because of the failure to comply with a ruling of the Superintendence of Industry and Commerce, in January 2016, which ordered the construction firm Alsacia CDO to return 13,380 million pesos to about 70 owners of the development (Tiempo, 2018).

The maximization of profits by optimizing materials and spaces to the limit was expressed with the collapse of Space and other buildings that may have to be demolished or repaired, this semi-paralyzed the real estate trade of high-rise buildings in Medellin, especially in the El Poblado sector, which at the time was an alternative to obtaining great wealth, appropriating the urban surplus value.

The topography of El Poblado sets limits to real estate greed, and nature has sent its deadly messages with the Cola del Zorro and Alto Verde landslides in recent years. These kinds of events may be repeated in the future given the characteristics of the creeping, shifting soil in the hills of El Poblado. However, the Space event is unique in that it is not caused by nature, an earthquake, or an earthquake. Space fell to a long experienced and renowned company due to possible structural failures. Only in Medellín, the most innovative city, paradoxically, does a building fall due to construction failures. In this sense, it is imperative for the authorities, starting with the Mayor and the City Council, to take advantage of the crisis to impose stricter and more severe conditions for construction in El Poblado and the city in general through the POT.

A study by anthropologist Paula Sanín Naranjo, March 2010. As a consequence of the approval of Medellin's Land Use Plan in 1999, considerable benefits were given to the subdivision structure, which generated great advantages for building activity and triggered construction activity. A disproportionate growth in an area is considered a symbol

of prestige and exclusivity. To such an extent that in recent years 30% of the city's buildings are in El Poblado.

With growing problems of traffic congestion and environmental pollution, this alternative center of Medellín, in addition to being a reference of better social status, represents the first context to be clarified regarding the collapse of tower 6 of the Space building. In a relatively short time, the area went from being a rural and rural territory close to the mountains in the southeastern sector of the city to an active commercial and housing area, with multiple apartment buildings and a sense of collective security, but a poorly planned development.

In this perspective, after the collapse of tower 6 of the Space building, which destroyed 84 apartments in seconds, the first questions fell on the Second Curator's Office of Medellín. It is worth remembering that the curators emerged in 1994 to decongest the planning offices of the municipalities and speed up the processing of construction licenses, which sometimes took up to five years. The problem is that the issue went the other way and, particularly in Medellín, the real estate boom multiplied their management (Espectador, 2013).

After the disaster, it is now clear that there is a need for more control over the activity of the curators. At least in the capital of Antioquia, with the POT updated in 2006, which stimulated construction in areas such as El Poblado, it is clear that greater vigilance is urgently needed. In the case of the second curator Carlos Alberto Ruiz, today in the eye of the hurricane, he is initially questioned for being the one who granted the urbanization license for the general project and then approved the different stages of construction of the residential unit.

One of the consequences of ignoring or failing to comply with parts of the seismic-resistant standard was the modification of said standard; the engineers who performed the calculations decided to leave aside parts of Law 400 of 1997 (standards on seismic-resistant constructions are adopted); in addition, 10,678 transgressions were made to technical seismic-resistance standards. It was determined that the seismic design parameters were not established or defined and that the mezzanine slabs did not have the minimum stiffness required to limit deflections or other deformations that could impair the strength and functionality of the structure.

One of the changes was the issuance of law 1796 of 2016 known as '*safe housing law*' whose purpose is focused on generating measures towards the protection of the home buyer, increase in the safety of buildings, strengthening the public function exercised by urban curators, and likewise establishing other functions to the superintendence of notary and registry.

The issuance of this new law also brought modifications to Law 400 of 1997 in articles (15, 18, 19) affecting the technical regulation of seismic resistant constructions (NSR), as well as creating the national registry of professionals for the NSR accredited to carry out design, review, and supervision of Law 400 of 1997.

It should be noted that one of the causes of the construction of the towers is due to negligence on the part of the urban curator Carlos Alberto Ruiz Arango, who granted the construction licenses for the different phases of the Space building, after which the Attorney General's Office decided to dismiss him and disqualify him for 8 years.

Edgar Mauricio Ardila Vélez (structural reviewer of the project), Pablo Villegas Mesa (legal representative of the construction company LERIDA CDO), María Cecilia Posada Grisales (engineering director of the work), and Bernardo Antonio Vieco Quiros (responsible for the soil study), all of whom had their professional licenses canceled for different periods as shown in table 5.

Table 5
Detail of penalties imposed on employees.

OFFICIAL	PENALTY
Eng. Jorge Aristizábal Ochoa	Cancellation of professional license
Eng. Edgar Mauricio Ardila Vélez	Cancellation of professional license
Eng. Pablo Villegas Mesa	Cancellation of professional license for 22 months
Eng. María Cecilia Posada Grisales	Cancellation of professional license for 20 months
Eng. Bernardo Antonio Vieco Quirós	Cancellation of professional license for 6 months

Another effect of having made the wrong calculations, designs, etc., resulted in a request from the Medellín mayor's office to the engineering faculty of the Universidad de Los Andes to carry out the pertinent studies, evaluations, and diagnoses in four phases (Andes, 2015).

1. Preparation of a technical concept on the Space building about compliance or non-compliance with the legal technical standards applicable to the design and construction processes of the foundation, structure, and non-structural elements.

2. Development of a concept, supported by international experts, on the general conceptualization of the project, the main shortcomings, and problems it presented in light of the state of the art of knowledge and applicable world practice.

3. Conduct the detailed technical studies required to assess the most probable causes of the collapse of Stage 6 of the Space building.

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4. Studies, evaluations, diagnoses, and recommendations about the Continental Towers and Asensi buildings for which the Mayor's Office required a technical concept for decision-making purposes related to their safety and functionality.

Conclusions

It has been a little more than five years since the collapse of this building, which has generated great uncertainty about the work of civil engineers when undertaking a project of this size, but despite this, it has left a cold lesson to engineering to take more precautions about the area where it is built, the design and the materials used, since it is a residential construction and the first factor to take into account is the safety of the people who live in it, since that is the main objective of the engineer to create structures that support everything to which it is subjected.

These collapses are not only related to negligence on the part of those in charge of the construction, but also to corruption in these projects, since unauthorized cuts are made in materials and studies related to the building.

In this article we wanted to show the crude reality facing our country, negligence on the part of our large construction companies and professionals in the field of civil engineering since we do not know if more constructions like these, fortunately, have not yet collapsed; another purpose of this article is to inform the people who were always interested in why this building collapsed since unfortunately there was no good information about this case in the media.

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Instrucciones para los autores

Tekhnê
Tecnología al servicio de la sociedad
Universidad Distrital Francisco José de Caldas - Facultad Tecnológica

Revista Tekhnê
Universidad Distrital Francisco José de Caldas
Facultad Tecnológica

Alcance y política editorial de la revista

La revista **Tekhnê** es una revista institucional de la Facultad Tecnológica de la Universidad Distrital Francisco José de Caldas (Colombia). Es arbitrada, y acepta trabajos originales en el campo de la ingeniería, la tecnología y las ciencias aplicadas, con la condición de que sean producto de trabajos de investigación. Desde su primer número en el año 2003, la revista ha mantenido su regularidad.

Posee un carácter científico-académico, y atiende a la comunidad nacional e internacional especialista en áreas de ingenierías eléctrica, electrónica, mecánica, de sistemas, industrial y civil. Publica resultados de investigación en inglés (artículos originales e inéditos), y está completamente abierta a especialistas de todo el mundo en calidad de autores y/o lectores. Es arbitrada mediante un proceso doble ciego, con rotación continua de árbitros.

La revista **Tekhnê** posee una periodicidad semestral, coincidente con los semestres académicos de la Universidad Distrital. La publicación se realiza los meses de junio y diciembre de cada año. El proceso de evaluación de los trabajos sometidos para la publicación contempla una etapa de aceptación inicial por parte del Comité Editorial, quien verifica el cumplimiento de los parámetros editoriales, y una evaluación por pares académicos mediante un proceso doble ciego. El tiempo que toma decidir sobre la aceptación de un trabajo nunca supera los seis (6) meses a partir de la fecha de recepción.

La revista **Tekhnê** está comprometida con altos estándares de ética y toma las medidas posibles para evitar las malas prácticas como el fraude y el plagio. Todos los autores deben declarar que sus manuscritos son originales, inéditos y de su autoría, condición necesaria para ser considerados por el Comité Editorial. La revista **Tekhnê** también se compromete a garantizar una justa, objetiva y rápida revisión de los manuscritos tanto por árbitros como por parte del Editor. Los autores reconocen que han dado a conocer cualquier conflicto real o potencial de intereses con su trabajo o de beneficios parciales asociados a través de la cesión de derechos.

La revista **Tekhnê** es financiada por la Universidad Distrital Francisco José de Caldas, razón por la cual NO cobra por procesamiento y/o publicación de artículos (APCs).

Tipos de artículos aceptados

La revista publica exclusivamente artículos de Investigación Científica y Tecnológica (según clasificación del Índice Nacional de Publicaciones Científicas y Tecnológicas Publindex de Colciencias), los cuales se caracterizan por presentar resultados originales de proyectos terminados de investigación, con secciones claramente diferenciadas de introducción, metodología, resultados y conclusiones. Otro tipo de artículos como los denominados de reflexión, revisión, artículos cortos o reportes de casos no son aceptados, y serán rechazados por el Comité Editorial sin surtir proceso alguno de evaluación.

Formato del manuscrito

En cuanto a estructura, deben ser evidentes las secciones de introducción, metodología, resultados, conclusiones y referencias. El resto del documento se debe conformar en concordancia con su contenido. La longitud no debe superar las 25 páginas en su totalidad. En la parte inicial de la primera página se debe incluir: (1) Un título del manuscrito (en español e inglés), corto, descriptivo del contenido y atractivo para el lector. (2) Nombre completo de los autores y detalles de afiliación institucional, incluido correo electrónico. (3) Resumen (en español e inglés) del manuscrito con un tamaño máximo de 250 palabras, que establezca el objetivo, la metodología, los resultados y principales conclusiones. (4) Palabras claves, máximo cinco, en minúsculas y separadas por comas.

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Para cualquier solicitud de información adicional puede comunicarse con:

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Instructions for authors

Tekhnê
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Tekhnê Journal
Universidad Distrital Francisco José de Caldas
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Scope and editorial policy of the journal

The **Tekhnê** journal is an institutional journal of the Technological Faculty of District University Francisco José de Caldas (Colombia). It is arbitrated, and accepts original articles in the field of engineering, technology and applied sciences on the condition that they are the product of research work. Since its first issue in 2003 the journal has maintained its regularity.

It has a scientific-academic nature and attends the specialist national and international community in the areas of electrical, electronics, mechanical, systems, industrial and civil engineering. Publishes research results in English (original and unpublished articles), and is fully open to experts from around the world as authors and/or readers. It is arbitrated by a double-blind process, with continuous rotation of evaluators.

The **Tekhnê** journal has twice a year periodicity, coinciding with the academic semesters of the District University. The publication is made in June and December each year. The evaluation process of the papers submitted for publication includes a stage of initial acceptance by the Editorial Committee, which verifies compliance with the editorial parameters and an evaluation by academic peers through a double blind process. The time taken to decide on the acceptance of a paper never exceeds six (6) months from the date of receipt.

The **Tekhnê** journal is committed to high ethical standards and take possible measures to avoid bad practices such as fraud and plagiarism. All authors must declare that their manuscripts are original, unpublished and of his own, needed condition to be considered by the Editorial Committee. The **Tekhnê** journal also is committed to ensuring a fair, objective and quick review of manuscripts both referees as by the Editor. The authors recognize that they have disclosed any actual or potential conflict of interest with their work or partial benefits associated through the transfer of rights.

The **Tekhnê** journal is funded by the District University Francisco José de Caldas, which is why it does NOT charge for processing and/or publishing articles (APCs).

Types of articles accepted

The journal publishes only Scientific and Technological Research articles (as classified by Publindex, the National Abstracting and Indexing System for Serial Publications in Science, Technology and Innovation of Colciencias), which are characterized by original results of completed research projects with clearly distinct sections of introduction, methodology, results and conclusions. Other articles as called reflection, review, short articles or case reports are not accepted and will be rejected by the Editorial Committee without dispensing any evaluation process.

Manuscript format

Regarding the structure, should be evident the sections of introduction, methodology, results, conclusions and references. The rest of the document must conform in accordance with its contents. The length should not exceed 25 pages in full. In the initial part of the first page should include: (1) A manuscript title (in Spanish and English), short, descriptive of the content and attractive to the reader. (2) Full name of the authors and institutional affiliation details, including email. (3) Abstract (in Spanish and English) of the manuscript with a maximum size of 250 words, which set the objective, methodology, results and major conclusions. (4) Keywords, up to five, lowercase and separated by commas.

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Authors must submit their articles through the application for the purpose of the Open Journal System (http://revistas.udistrital.edu.co/ojs/index.php/tekhne/index) in digital format, attaching:

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The presentation letter should be addressed to the director and editor of the journal Prof. Fredy H. Martínez S., and it should include:

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