Tekhnê

Tecnología al servicio de la sociedad

Universidad Distrital Francisco José de Caldas - Facultad Tecnológica

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- Superior izquierda: Block diagram of the closed-loop system (Saa, J. and Cucanchon, M.)
- Superior derecha: Comparison of the assumed model and curve of the laboratory data (Saa, J. and Cucanchon, M.)
- Centro: Location of poles and zeros of the transfer function (Saa, J. and Cucanchon, M.)
- Inferior izquierda: Code in MATLAB (Saa, J. and Cucanchon, M.)
- Inferior derecha: Permeable pavement without infiltration (Tobar, M. and Jaimes, H.)

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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.

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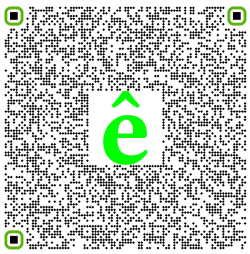

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- Top right: Comparison of the assumed model and curve of the laboratory data (Saa, J. and Cucanchon, M.)
- Middle: Location of poles and zeros of the transfer function (Saa, J. and Cucanchon, M.)
- Lower left: Code in MATLAB (Saa, J. and Cucanchon, M.)
- Lower right: Permeable pavement without infiltration (Tobar, M. and Jaimes, H.)

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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.

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The journal is aimed at professors, researchers, students, and professionals interested in permanently updating their knowledge and monitoring scientific research processes in the field of engineering.

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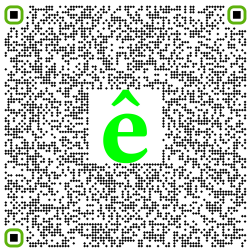

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El comité editorial de la revista **Tekhnê** está comprometido con altos estándares de ética y buenas prácticas en la difusión y transferencia del conocimiento, para garantizar el rigor y la calidad científica. Es por ello que ha adoptado como referencia 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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En su calidad de máximos responsables de la revista, el comité y el equipo editorial de **Tekhnê** se comprometen a:
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• Asegurar la calidad del material que se publica.
• 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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Los lectores estarán informados acerca de quién ha financiado la investigación y sobre su papel en la investigación.

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Tekhnê se compromete a asegurar la calidad del material que publica, informando sobre los objetivos y normas de la revista. Las decisiones de los editores para aceptar o rechazar un documento para su publicación se basan únicamente en la relevancia del trabajo, su originalidad y la pertinencia del estudio con relación a la línea editorial de la revista.

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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En caso de detectarse algún trabajo cuyo contenido sea fraudulento, será retirado tan pronto como se conozca, informando inmediatamente tanto a los lectores como a los sistemas de indexación.

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Tekhnê establecerá los mecanismos necesarios para evitar o resolver los posibles conflictos de intereses entre autores, evaluadores y/o el propio equipo editorial.

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Cualquier autor, lector, evaluador o editor puede remitir sus quejas a los organismos competentes.

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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.

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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.

Peer review process

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Claims

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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Tracking malpractice

Tekhnê accepts the obligation to act accordingly in case of suspected malpractice or misconduct. This obligation extends both to publish and unpublished documents. The editors not only reject manuscripts with doubts about possible misconduct, but

they are considered ethically obligated to report suspected cases of misconduct. From the journal every reasonable effort is made to ensure that works submitted for evaluation are rigorous and ethically appropriate.

Integrity and academic rigour

Whenever evidence that a published work contains significant misstatements, misleading or distorted statements, it must be corrected immediately.

In case of any work with fraudulent content is detected, it will be removed as soon as it is known, and immediately informing both readers and indexing systems.

Practices that are considered unacceptable and as such will be reported: simultaneous sending of the same work to various journals, duplicate publication with irrelevant changes or paraphrase of the same work, or the artificial fragmentation of a work in several articles.

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The relation between editors, publishers and owners will be subject to the principle of editorial independence. **Tekhnê** will ensure that articles are published based on their quality and suitability for readers, and not for an economic or political gain. In this sense, the fact that the journal is not governed by economic interests, and defends the ideal of universal and free access to knowledge, provides that independence.

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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.

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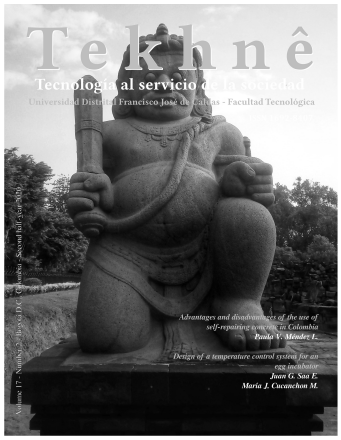

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Editorial

Si bien se han comenzado a relajar las restricciones de aislamiento en el país, en lo que se ha denominado cuarentena selectiva, lo cierto es que la pandemia a causa del COVID-19 se mantiene, y en consecuencia, en su gran mayoría, los espacios de formación superior mantienen cerradas sus instalaciones. Para este mes de diciembre se espera la llegada del tercer pico de esta pandemia, el cual, según los expertos, será el más crítico en cuanto a número de personas contagiadas, y por supuesto, número de muertes. A la fecha de publicación de este número se cuenta un promedio de 15 mil contagios nuevos y 200 muertes al día. Además, según las noticias más recientes, las primeras vacunas llegaran al país durante el primer semestre de 2021.

Con este panorama, es claro que las instituciones de educación mantendrán el esquema de formación a distancia apoyado por Tecnologías de la Información y las Comunicaciones (TIC). Muchos han sido los problemas que se han tenido que afrontar, y que continuarán en los próximos meses. Muchos espacios de formación requieren de trabajo especializado en laboratorio, algo que tanto estudiantes como docentes reclaman constantemente. Además, los jóvenes estudiantes comienzan a sentir la presión del aislamiento en una sociedad actual altamente dependiente de la comunicación y la socialización.

Aun así, hay estudios que muestran que estas estrategias de formación a distancia han traído ventajas al proceso. Se ha reportado que los estudiantes tienden a enfocarse mucho más en sus procesos de aprendizaje al reducirse la distracción, lo cual ha tenido incidencias positivas en los niveles de responsabilidad en sus procesos de formación, y pensamiento autocrítico respecto a su realidad, y la realidad del mundo. Si bien se ha demostrado que los sectores más deprimidos económicamente son también los más afectados, el aislamiento ha logrado incrementar la capacidad de ahorro, lo que también incide en la formación y la conciencia social. Si bien aún falta mucho por vivir de esta pandemia, las vacunas cambian las reglas de juego a nuestro favor, y son el primer paso a alguna normalidad que nos lleve a una estabilidad similar a la de un año atrás.

Prof. Fredy H. Martínez S., Ph.D
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Editorial

Although restrictions on isolation have begun to be relaxed in the country, in what has been called selective quarantine, the truth is that the pandemic due to COVID-19 continues, and consequently, the vast majority of higher education institutions have kept their facilities closed. The third peak of this pandemic is expected to arrive this December, which, according to experts, will be the most critical in terms of the number of people infected and, of course, the number of deaths. As of the date of publication of this issue, an average of 15,000 new infections and 200 deaths per day have been reported. In addition, according to the most recent news, the first vaccines will arrive in the country during the first semester of 2021.

With this scenario, it is clear that educational institutions will maintain the distance learning scheme supported by Information and Communication Technologies (ICT). Many problems have been faced and will continue to be faced in the coming months. Many training spaces require specialized laboratory work, something that both students and teachers are constantly asking for. In addition, young students are beginning to feel the pressure of isolation in today's society, which is highly dependent on communication and socialization.

Even so, there are studies that show that these distance learning strategies have brought advantages to the process. It has been reported that students tend to focus much more on their learning processes by reducing distractions, which has had a positive impact on the levels of responsibility in their training processes, and self-critical thinking regarding their reality and the reality of the world. Although it has been shown that the most economically depressed sectors are also the most affected, isolation has managed to increase the capacity to save, which also has an impact on education and social awareness. Although there is still a long way to go in this pandemic, vaccines change the rules of the game in our favor and are the first step to some kind of normality that will lead us to stability similar to that of a year ago.

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What is a smart road?

¿Qué es una carretera inteligente?

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A smart road is the planning of avenues or roads that become advanced intelligent platforms, which allow detailed infrastructure to embody or develop their functions (such as traffic signals and tolls). It allows vehicles to communicate and share an essential information base with deterministic characteristics between a system for receiving and exporting information. In this way, a driver can know in advance if a traffic accident has occurred or if weather conditions are making it difficult for vehicles to pass. This article documents several characteristic aspects of the functioning of each of the parts that make up the intelligent highway.

Keywords: Environment, intelligent road, solar panel, transportation, vehicle

Una carretera inteligente consiste en la planeación de avenidas o caminos que se conviertan en avanzadas plataformas inteligentes, que permiten que la detallada infraestructura plasme o desarrolle sus funciones (como señales de tránsito y peajes). Permite que los vehículos se comuniquen y compartan una base información esencial con características determinantes a los factores, entre un sistema de recepción y exportación de información. De esta manera, un conductor puede conocer con anticipación si se registró un accidente de tránsito o si las condiciones climáticas están dificultando el paso de vehículos. Este articulo documenta varios aspectos característicos del funcionamiento de cada una de las partes que componen a la carretera inteligentes.

Palabras clave: Carretera inteligente, medio ambiente, panel solar, transporte, vehículo

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Introduction

A smart road, someday we thought that mankind would have engineered every technology seen today when we used to think about the future as children, did we imagine a future like this? This is the beginning of the evolution of transportation mechanisms in different countries (Nallaperuma et al., 2019; Wolf & Korzynietz, 2019). Not only benefiting man but also to the planet earth causing less damage to the environment, its surroundings, people, among other factors, where one of its main functions is that they will be able to store large amounts of information on various factors of interest of the roads, in this sense will be able to develop elements of the roads that will serve to prevent, report and respond to certain circumstances such as weather changes, the volume of traffic on roads and occurrence of damage to them, locating every possible error preventing accidents or failures in its structure (Hernández et al., 2019).

It could be a global mechanism, but it is not economically feasible because it does not only concern a field, but also represents various models of use not only in roads, but also in other structures, involving the economy, the environment, resources, materials, and so on (Faieq et al., 2019). It requires a great deal of agility, dynamism, and the will and capability to move into new areas, with lower-cost products that can be followed by other sectors of activity.

This type of road functions as a mechanism for mobilizing vehicles and pedestrians, directly to road vehicles with their physical environment in the first place, to improve road safety (Gichaga, 2017). The technology is based on several disciplines, including transportation engineering, electrical engineering, automotive engineering, and computer science (Cohen et al., 2019). it specifically covers road transportation, although similar technologies are in place or under development for other modes of transportation (de Clercq et al., 2019). Aircraft, for example, use ground beacons for automatic guidance, allowing the autopilot to fly without human intervention. In highway engineering, improving the safety of a road can improve overall efficiency. Aim for improvements in safety and efficiency (Kim et al., 2015; Siuhi & Mwakalonge, 2016). Some readers may know the guidance system's loop opposite to its algorithms.

Smart road

The main goals of road sustainability, efficiency, and safety are that these avenues or roads become advanced platforms that allow infrastructure (such as traffic signs and tolls) and vehicles to communicate and share essential information between a system for receiving and exporting information (Jamroz et al., 2019). In this way, a driver can know ahead of time if there has been a traffic accident or if weather conditions are making it difficult for cars to pass through a certain point, so the driver knows which road to take and if it is a good decision, so that, with the help of navigation systems, he can receive recommendations for alternative routes and reduce waiting times for people inside a vehicle, while also reducing gasoline consumption and the associated emissions.

Among the various features and functions that intelligent roads can provide for humans, one is that it helps the environment by reducing several compounds that harm it by polluting the air, soil, and producing poisoning, among other things. They contribute to more efficient and less polluting transportation management, lowering the carbon footprint, promoting sustainable mobility policies, and improving air quality by reducing emissions associated with traffic congestion.

They will be able to store large amounts of information on various road factors of interest, allowing them to develop road elements that will serve to prevent, report, and respond to certain circumstances such as weather changes, the volume of traffic on roads, and the appearance of flaws in them, locating every possible error preventing accidents or failures in its structure. Having a digital copy of the world is extremely useful because it allows us to measure faster, calculate more accurately, and plan in ways that were simply not possible two years ago.

This change is currently being developed by private entities, but more governments are getting involved with the new technology of the future, seeing the changes that can be generated, not only locally, but also globally, since as we know the world powers have a competition of superiority to determine which one has the best technological, economic, political and social advances.

The first postulation of this project was proposed as a traffic control mechanism indicating the function of preventing accidents such as stalemates resulting from human error, technology can ensure that response teams such as ambulance, firefighters, police, among others. Have priority in their movements, so that if it is an emergency to reach the destination optimally. Showing several aspects to have in front of the innovative project of the intelligent road generating a broad knowledge and timely basis, to support the feasibility and possibility of development in each country of the world involving costs and others, so that each ruler see the possibility that has this new acquisition of intelligent structures, identifying what benefits can acquire its territory.

The human being as a society will not be so difficult to adapt to these new roads, because nowadays, everything is digital. Society is already intimately related to any technological mechanism with various factors to meet the needs requested, including evolving to adapt to technological innovations that the automotive sector and transport systems demand, with the great possibilities that can generate by providing energy to vehicles, because the roads of the future

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are not only intelligent due to their ability to communicate with other objects, but they can also supply energy to the vehicles that travel on them.

To achieve a true transportation revolution by 2030, 15% of vehicles could be autonomous, where sustainability, efficiency, and road safety will be the main objectives (Jochem et al., 2015). Sensors will be placed on these roads to measure traffic density and the speed at which vehicles circulate, thus changing the speed limits of the illuminated signs and adapting them to the flow of vehicles. The intelligent road is an ally of autonomous vehicles through recharging, without the need for fuel, projecting less burden on ecosystems.

Different types of smart roads

Different mechanisms have emerged from the intelligent roads one from the other, looking for better efficiency according to their location, demonstrating, which would adapt better to the situation posed by a country, of the different roads that may arise in the future and that already exist today, each with different functionality, but giving a benefit to all types of vehicle or system assigned, in such a way giving to know that there is not only a type of road but from them come other classifications according to the utility that presents or requests the location of this same (Toh et al., 2020).

The thinking of a society that is still based on the past and does not look to the future. But the basic mechanics are still there. The classic wheel, whether in natural rubber tires, synthetic tires, or futuristic proposals such as tubeless wheels, is still present in search of better development and thus continues to innovate in all kinds of mechanisms favored by nature, avoiding environmental destruction while assisting a man in the structure in the path of its path. One of them is the roads that were created by the Romans, this innovation in transport infrastructure are intelligent roads where they use photosensitive paints in road markings, which also have the function of climatology, generating informative symbols on the pavement of the roadway, road that allows to generate energy on the route itself and to recharge the batteries while driving the vehicle. Among other innovations over time are concrete, aqueducts, and floating bridges.

Solar roads and dynamic vehicle charging

We have been trying for quite some time to implement this type of structure that can be used in combination with other technologies embodied with the use of solar panels from an inexhaustible source of energy, which is the sun, since this asphalt absorbs these tensions very well, conducting it towards the whole system, where it detects the heat transforming it into energy in such a way making the capture of paintings or traffic signs in the hours of the night or during the day.

Through the use of LED lights in traffic lights, using solar energy without the need for other fossil energy, thereby drastically reducing carbon emissions (Xie et al., 2017). Solar panels are used to capture electromagnetic radiation from the sun for subsequent energy transformation. The dynamic charging of vehicles was tested in France to determine failures in the creation of this because there are problems in the load to vehicles by the power it generates or the speed of the vehicle while traveling the road, the fall of leaves to cover the solar panels preventing the best collection of solar rays, the deterioration of the road by the weights and vibrations caused by heavy vehicles, so it serves as an example to detect which areas to improve so that the next implementation of this is already complete and put for an indefinite time.

Smart pavement and connected roads

The modality of this intelligent road involves the interconnection between the road and the rest of the structure to improve the assistance that the security services or accident detection have, seeking to save lives, avoiding many pedestrian accidents, crossing red lights, with a sensor that facilitates the visualization of pedestrians, animals, and objects (Shi, 2020; Sun et al., 2018).

Along with the road, new materials are created or used for the construction of this, seeking to expand the knowledge of the use of more favorable resources such as plastic.

It initiated several projects in 2017 where plastic was used as a material to build roads (Appiah et al., 2017), constructing two private roads using the equivalent of 120,000 plastic bags. In addition to reducing pollution, plastic roads are more resistant to atmospheric weather and vehicles that deteriorate ordinary asphalt roads. It is estimated that they can last more than 50 years, three times longer than a conventional road, withstanding extreme temperature, protecting the solar panels or the technology involved in it, showing a different material than the conventional one.

In a didactic manner, using photographs or digitally formed pre-visualization, plans, and data tables, demonstrating the process and elements that comprise a normal road, next to an intelligent one, demonstrating the viability of both products launched to the market, putting into practice both models, highlighting which is more optimal for a society that is constantly changing, improving an economic model to a different and not-so-distant future (Xiao et al., 2017).

Road

A road has several components that are regulated by the amount of income provided for the work, determining the type of material, costs, location, among others, with the capacity to support heavy vehicles such as trucks, dump

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trucks, tractors (Abed, 2020; Niestroj et al., 2018). Engineers are always looking to improve their construction and innovate society. Innovative materials for the construction of new roads, using potentially less polluting and more durable raw materials without the additional costs of cement and other expensive resources, demonstrating the process of plastic reduction and reusing in an autonomous manner. The concept of an environmentally friendly intelligent road is being proposed.

For the effective design of a road, there are certain requirements by the INVIAS entity, which is in charge of regulating the designs of these, these are the following:

- Physical elements of roads
- Right of way or right of way strip
- Number of lanes of the standard section
- Berms
- Pumps
- Superelevation
- Slopes, ditches and others

Energy types

Energy is fundamental to our civilization. There are two kinds of energy, renewable (photoelectric, solar, wind and biomass) and non-renewable (mechanical energy, heat energy) (Qi et al., 2018). The basic and main source of energy is found in the sun, since the origin of the universe is present, it provides us with light and heat, this exerts a strong gravitational pull on all the planets of the solar system, as a mechanism of energy in the application of another type, the traditional, showing an alternative for society and the earth.

Among others it is found in the wind and water and even by the movement energy is generated, it is necessary for the development of mankind, in all fields of its technological activity, demonstrating in its percentage usefulness around the world.

Solar panel

Solar is inexhaustible and renewable energy, for the production of electricity or the production of heat. It can be stored with solar thermal collectors. They absorb radiation from the sun thanks to the set of crystals of a semiconductor material such as panels or mirrors to absorb and concentrate solar heat, transfer it to a fluid and conducted through pipes for use in buildings, brings advantages such as non-polluting, contributes to sustainable development and employment generation.

It is a reusable energy mechanism, in favor of recharge by heatwaves, as a mechanism of reception and adaptation to generate a basic function of a structure, giving rise to a new sense of use to various technologies. According to NASA, solar energy will never die because the sun still has 6.5 billion years of life left (Corkish et al., 2016).

Operation

Devices that capture solar electromagnetic radiation for later use and transformation into various forms of useful energy, such as thermal energy.

Solar panels absorb radiation from the sun thanks to the set of crystals of semiconductor material that compose them: crystalline silicon, and that when connected respond to the photovoltaic effect, according to which certain matter can emit electrons when bombarded with electromagnetic radiation, this element, as a generator of a new body, capable of transforming it into energy projected to a mechanism with a particular function.

The important role of the civil engineer in the development

The advancement of civil engineering has been and will continue to be a determining factor in the development of mankind, as the primary factor in the innovation of architectures or constructions under a government-agreed-upon regime of standards that evolves in tandem with technology, where it employs a variety of implementation tools to advance and improve the efficiency of modern seismic-resistant constructions When it comes to determining the primary role of the civil engineer in the field of civil engineering, innovation has evolved into an attitude.

Among the works built in the last century, perhaps the most responsible for having contributed greatly to the environmental deterioration of the country was the construction of the road network that today connects part of the territory and that often constituted new and uncontrolled fronts of deforestation and colonization. There is about 45,000 km of roads, built mainly in the last 80 years. However, what was at the base of the construction of most of them was the previous existence of isolated communities, settled and rooted in the most diverse places of the national geography and that legitimately aspired to enjoy access and vehicular communication. Therefore, it can be said that what failed in many cases was not the layout and construction of the highways but the capacity of the State to rationally order and control the use of the territory and to protect numerous areas whose vocation and strategic use was the conservation of their natural state, generating awareness about the evolution of civil engineering in Colombia, with previous and future projections, generating a process of professional ethics that incorporates environmental values and that puts the interests of society in general, including future generations, before private interests.

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Therefore, it can be said that what failed in many cases was not the layout and construction of the roads, but the State's capacity to rationally order and control the use of the territory and to protect numerous areas whose vocation and strategic use was the conservation of their natural state.

The orientation that influenced the evolution of Colombian infrastructure, as in most engineering projects, was to reduce investment and maintenance costs, but without taking into account the environmental impacts, which are not assumed by the project executors but directly by the people and communities affected.

Smart Roads: Technology cocktail

When we say smart road, we think of prioritizing the environmental study in the development of its road projects to generate the least impact on the site and reduce emissions in transportation. Some examples are the design of layouts capable of reducing traffic accidents that promote traffic jams, situations that cause the highest pollution peaks.

Furthermore, we carry out the prevention, healing, and conservation of the environments in which we work, integrating replacement tasks around the project with the planting of trees and shrubs while respecting the environment's flora, fauna, and cultural heritage.

The commitment to these technologies helps to reduce accidents and improve the safety and security of travelers and infrastructure, making them more efficient and optimizing the use of public resources, and assisting in the management of less polluting transportation, reducing the carbon footprint by promoting sustainable mobility policies, improving air quality due to emissions associated with traffic jams (Fig. 1). One of the goals on the agendas of governments and administrators around the world is to develop sustainable mobility, this idea of sustainable mobility is important, given that in 2050 more than 70% of the world's population will reside in large cities, needing to mitigate the problems of congestion, lack of capacity, pollution and road safety problems favoring the protection of people.

By incorporating intelligent technology for incident management, the system guides the operator to act correctly in each case, making the daily operation simple and efficient. The rise and need for safe and green mobility have prompted companies to include these technologies and developments in future projects by detecting traffic intensity in real-time and providing data such as traffic density, vehicle type, occupants, and other variables to support fare calculation.

One of the artificial intelligence is Big Data where it can be applied to traffic and flow prevention, but also to intelligent fleet management, providing real-time information on positioning, waiting for times and schedules of the public transport network, there is also BIM which is a building model that allows the management of large amounts of data and the generation of a digital twin of the physical structure to analyze its behavior.

Figure 1

Remote sensor (Valerann, 2020).

Among its many applications on the road, these include dynamic pricing solutions, detection of occupants in vehicles at high speed or in remote control, management and maintenance of control centers and operators on the road, improving safety and efficiency levels. A distributed acoustic sensor is capable of converting tens of kilometers of fiber optics into thousands of vibration sensors to classify events, generating different types of alarms such as activity and construction, vehicles, intrusion of people. This can be especially true in automated tolls, taking care of payments that are transmitted properly, without errors, electronically where not only the connectivity of the systems is guaranteed but also its low latency; therefore, the network and computing helps the connected devices to be functional and efficient at any time.

The smart road involves the interconnection between the road and the rest of the infrastructure, as well as with vehicles and pedestrians giving emerging mobility solutions as it will adapt to the infrastructure maintaining conversations with each other, this is a key piece in smart roads, as this will inform the driver that a pedestrian is crossing the street that has not yet been accessed, avoiding many road accidents, especially when there is no human contact.

The potential effectiveness of intelligent road knowledge directed to a few lucky countries for pilot tests, detonating several flaws discovered today or potential problems in the future, where this new technology is not implemented in the world, resulting in technologically backward cities that are unprepared for change and remain in a backward loop.

Countries where smart roads have been implemented

The intelligent road has only been implemented in a few selected countries where they work to determine the quality tests to these same and be improved over time, including England, Japan, France, and the United States, among others,

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to exploit the best qualities of the intelligent road (Collier & Weiland, 1994).

It is predicted that in a future time the whole world will be able to install these intelligent roads, improving the economy of a country, the environment, influencing the knowledge of engineers and architects, so that they can manufacture them effectively, placing them in certain cities. Society wants to look for a better alternative for all, but the population does not look for a solution, they let the leaders choose the best for them because the people do not know what is an intelligent road, functions, application, development, among others; since the rulers have not embodied this type of information so that the people begin to investigate and know this technological structure, some countries fail to see the importance of implementing these new technologies for fear that could mean losses for them, but for the people, it would be a benefit. A problem to handle is that the population does not know what an intelligent road is.

What is a smart road?

The smart road is a form of evolution of a new technology to serve society, thus improving several aspects to the driver and taking care of the environment, through sensors and electric vehicle charging, also preventing accidents and thus decreasing deaths from crashes on roads. The road will enable technological integration in existing transportation roads, including functions such as power generation via solar panels, integration with autonomous vehicles and sensors, and structural maintenance monitoring systems, among others. It contributes to the improvement of vehicular mobility in large cities by constantly seeking to evolve and improve in all the determining aspects that are generated over time, thereby satisfying specific human needs. A study in the United States found that between 1996 and 2011, more than 12,000 people died as a result of winter-related precipitation (Black & Mote, 2015). More than 500,000 accidents occur each year as a result of winter weather, resulting in a variety of benefits.

A major function is the reduction of automobile fatalities, accidents, government and insurance costs, economic losses, and personal expenses. Vehicles communicate and share essential information between a system for receiving and exporting information. Know in advance if a traffic accident has occurred or if weather conditions are making it difficult for cars to pass through a certain point. It is also possible to receive recommendations for alternative routes and can reduce waiting times for people inside a vehicle. It reduces gasoline consumption and the consequent emissions derived from the use of fossil fuels. Consequently, it helps the environment by mitigating several compounds that deteriorate it by polluting the air, soil, producing poisoning, among others.

These systems allow storing large amounts of information on various factors of interest of the roads. With this information, it is possible to prevent, inform and respond before certain circumstances such as weather changes, traffic volume on roads, and the appearance of damage on them, locating every possible error, preventing accidents or failures in its structure. Specific benefits include:

- Coordination of response teams such as ambulance, fire, police.
- Illuminated pavement.
- Increased safety on highways underwater.
- Solar panels on the road.

Reasons for use

To know the aspects surrounding intelligent highways, as a method of improving a country, with a more accessible economy, seeking greater resistance or quality of materials when used in buildings.

- Know and interpret positively all the operations of intelligent highways.
- Recognize and identify the qualities that a civil engineer presents, looking for better use of the tools using technology.
- Recognize the environmental impacts that civil engineering can have with intelligent highways, determining if it is a good option to be used worldwide.
- Learn the importance of the civil engineer in seeking to always improve the quality of buildings.

Intelligent roads in Colombia

The problem lies in several aspects developed by events in Colombia regarding the intelligent road, the population is unaware of these types of concepts, since they do not know what is a road of this type and speculates around its function determining the possible causes that lead to this circumstance, it does not cause them any interest to deepen the reality of the subject, mainly because they doubt, The population is not aware of several factors that happen around the world, being biased national TV channels, demonstrating that it can be an intelligent road.

The intelligent road has received little attention or investment around the world because it was chosen for the project by a small number of countries, as previously stated, and thus cannot be used by entities that are not linked, but at the time does not receive the necessary support to which it is requested, there is no knowledge of this structure, generating lack of information by channels or other issues of television connections, but is still present in magazines as recognized articles or social networks sponsoring.

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First smart road to open by 2030

The opening of a smart road is proposed for 2030 for postulation to unconnected countries because it will be proposed globally from that date (Aldegheishem et al., 2018). The high cost of producing and maintaining the current road network has compelled governments in many countries to take steps to reduce these costs. For this reason generating the idea of a smart road being an event presented to a way of changing the world, opening a new opportunity for society to produce less environmental pollution, motivating people to buy rechargeable vehicles in this way not only benefits the government but society itself, saving on harmful fuels for the ecosystem around us, giving opportunities to services such as police, ambulances, firefighters and others, from 2030 all economic model will change with greater efficiency and speed, showing a change never thought before. It seeks to expand the knowledge we have about smart roads, so that the idea is developed where it can be used in our country, seeking greater economy, and less pollution in the established constructions, seeing how all this important scheme is confirmed.

Scope and limitations

It could be a mechanism used globally, but it is not feasible for economic reasons, since it does not only concern a field, but represents various models of use not only in roads but also in other structures, involving the economy, the environment, resources, materials, among others.

But technology evolves exponentially every day, generating promoted events, making known what is a smart road, which it is acknowledged that new technological developments are permeating all aspects of human life, and transportation is no exception but is not known due to a lack of societal interest, thinking that it will be more difficult and higher cost at the time to translate it into a near reality, although the project is embodied over 10 years, which also causes this kind of disinterest in the launch date, and when it is known would already be in the future more embodied to the presentation of these.

Currently, cyberspace is the second digital and technological revolution, which consists of the globalization of information where it is captured, stored, reported, managed, and monitored all the news that is in their environment, to help humans to optimize all activities in their daily lives.

For the development of intelligent roads, we must be clear about some concepts such as technologies, software, and tools for the development of this using electronics, i.e. communication technologies.

Mobile communication networks

Both the transmitter and the receiver are or may be in motion. The mobility of these two elements at the extremes of communication makes the use of wires for communication at these extremes not feasible. The basic components of the mobile communication system are detailed below:

- Base Station (BS): These are fixed stations that are controlled by a control unit, these are low power transmission and reception equipment of various frequencies or channels, which fulfills the management of radio communications with some degree of signal processing through a radio link.
- Control Station (CS): These are fixed programmable control stations that automatically control data emissions and the operation of another fixed station, such as a base station; they are responsible for ensuring the integrity of the system and compliance with requested diagnostics.
- Repeater Station: (RS): These are stations used to retransmit received signals, increase coverage in low traffic areas, and allow coverage in an area not accessible by the base station.
- Station (MS): It is a station equipped for mobility that uses FM transmission.

WiFi networks

This means of communication is very useful for the development of everyday life, as it allows connectivity between wireless devices within the same network without the need to connect them by cables.

HOC networks

They are considered as temporary wireless networks of mobile nodes, since the network structure varies dynamically, as well as having a flexible communication system and routing services that retransmit packets between nodes that do not have direct wireless communication.

Wireless Sensor Network (WSN)

The network is composed of four essential elements such as sensors, nodes, gateway, and base stations. Sensors have two important characteristics: they are responsible for transforming data into electrical signals, and in turn are physically considered as nodes, which send the information received to a base station (responsible for receiving the data sent). Likewise, the nodes have three states: *Sleep*, a state that keeps the sensor in energy-saving mode; *Wake Up*, a transition state from *Sleep* to active mode; and *Active* is the state in which the sensor operates transmitting the information.

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Cellular levels

Cellular levels are highly dependent on the coverage and capacity required in the area to implement a cellular network. The following are found:

- Micro Cells: It is one of the fundamental communication models within a cellular network since it has the main characteristic of increasing the capacity of the network, whose coverage range is between 100 to 1 km, thus being able to have a very low transmission power, greater traffic handling, relatively low cost, and high efficiency.

- Macro Cells: It is one of the most operational communication models in a cellular network, whose coverage ranges from 1 to 30 kilometers; more common in users who are on the move (high speed).

- Pico Cells: It is a communication model that is characterized by increasing the traffic handling capacity, being used in areas where there is high packet traffic whose coverage range is less than 100 meters.

Programming components

- HTML: HyperText Markup Language, is a programming language that consists of text and tags used to define a web document with HTM or HTML extension, used to create web pages to give structure and shape to the content to be displayed.

- PHP: It is a widely recognized open-source programming language; it is used to generate dynamic web pages that can be embedded in HTML. It is used more in servers since they are in charge of receiving, reordering, and processing the data sent from a web address in a browser, making all this dynamic and interactive procedure and not in a static way.

- Python: It is an object-oriented programming language regardless of the development platform to be used, such as Unix, Windows, OS/2, Mac, among others. It is available for any type of program, Windows applications, network applications, and web pages for free; it was designed to generate script codes that can have fewer lines than its similar ones such as C or Java, which does not need to be compiled to be executed.

- JSON: can be read by any programming language, that is, it can be used for the exchange of information between different technologies, they do not need to speak the same language, the sender can be Java and the receiver PHP, each programming language has its library to encode and decode JSON strings.

- Database Manager: This system is completely free being of great utility, since it is not necessary to install some software, it can be found in most of the shared servers of web pages.

- Google API of web type: It is a visual interface programming application that provides access to a set of complete functions of general use for the customization of map information, which has lines of code in different languages such as Java Scripts ready for use.

Electronic programming software

- Servo Blaster: It is software that provides an interface that can control multiple servo motors through the GPIO pins of the Raspberry Pi. Servo motors usually need a high active pulse of between 0.5 ms and 2.5 ms, where the pulse width controls the servo position, which must be repeated approximately every 20 ms, having a high criticality since it directly drives the servo positioning.

- IDE: Arduino It is an integrated development environment known as IDE Integrated Development Environment), which is sophisticated for the compilation and execution of a series of previously programmed codes, the same that uses a USB type serial communication to be loaded into the integrated to be used.

- Proteus: It is an integrated software, which was designed to perform different construction projects of electronic equipment in all its stages, such as design, simulation, debugging, and construction, it is currently useful in almost all electrical and electronic projects.

- MikroC Version 6.6.1: It is an integrated development environment known as IDE (Integrated Development Environment) used to compile and execute a series of previously programmed codes, these are written in ANSI language understandable for any PIC microcontroller. It allows to generate files with extension .hex and code in assembler language being these compatible with other compilers.

From all the knowledge about the operation of the intelligent highway, as it has been possible to demonstrate an optimal operation in detail in the use of each part of this structure, the question arises: how can we make people know about intelligent highways? To solve these questions, it is necessary to know everything about the intelligent highway and the aspects that it involves.

The intelligent road, what is it? It is determined that by its characteristic name has many different functionalities, taking us to a technological future previously embodied as science

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fiction, but at this pace of evolution of humanity, we can bring here the phrase *reality beats fiction* leading us to a new world, but there is not only a type of intelligent road, there is variety, but a problem raised is a term little known locally and globally, because a smart road is directed to several points in specific, this mechanism will not only benefit man, its purpose or functionality goes further, knowing that it will also help the planet earth causing less environmental damage, being indispensable for economic, political and social development adapting to the changes of its exterior, using them as tools to evolve improving the situation of several countries or major cities, showing that the roads are the veins of a heart called country, as self-sustainable roads.

Intelligent roads were already destined for a year of presentation to the public, but it is still not clear what it is? Which is a form of evolution in the application of existing technology in various branches of self-sustaining generating service to society, improving various aspects related to vehicles such as the driver, mechanics, if the car and its environment caring for the environment, with its sensors and battery recharging electric vehicles (which in the year 2020, is gaining strength, for reasons that the vast majority of vehicles developed from 1839 begin to be electric, the road was mainly designed to prevent traffic accidents, involving pedestrians or if drivers *thus decreasing deaths* by crashes on roads. Life on Earth would be impossible without the energy provided by the sun, and without other energies, the development of our activity and progress would be impossible, helping to improve vehicular mobility in large cities, the human being always seeks to evolve improving in all possible aspects that are generated through time and history, satisfying human needs selective to each culture or present difference, a clear example of the lack of these roads and mistakes made by people. A study in the United States found that between 1996 and 2011, more than 12,000 people died as a result of winter-related precipitation. Every year, more than 500,000 accidents occur as a result of winter weather (Pisano et al., 2008).

Society does not allow new knowledge if they do not see the advantages developed, at first sight, generating ignorance of what is an intelligent road? They are uninterested in learning about this project because of the economic loss to their economy, a community's thinking that is still based on the past and does not look to the future. The basic mechanics are still present, as is the classic wheel, whether in natural rubber tires, synthetic tires, or even futuristic proposals such as tubeless wheels. Technology evolves, but the first archaic technologies are still present; it is a different way of looking at the community; the technologies developed today are derived from anything; these mechanisms have historical precedents, which can be shown that technology improves from one that no longer meets the needs requested for the current time (it does not disappear, it evolves creating new utilities showing that everything has an origin starting from an ancestor) because in this way to continue innovating in all type of mechanism favored by the nature avoiding the destruction of the home of each one of the people, which is the planet earth.

Helping the man in the structure of the trajectory of his path. We find the roads that were created by the Romans and was evolving until today, this innovation in transport infrastructure are intelligent roads, one of the main functions that can be evidenced is where they employ photosensitive paints on road markings for greater visibility, which also have as a function of climatology determining the changes that can happen warning the driver, generating informative symbols on the pavement of the roadway, also the road allows us to generate energy on the route itself and to recharge the batteries while driving the vehicles.

Main factors for lack of awareness of smart roads

The factors presented below are taken from the point of view of an average Colombian (Bogota).

- The population does not see the importance of a mechanism such as the intelligent highway because it is such a distant event.
- They consider that the manufacture of these large structures will affect the country's economy, and consequently their pocket, showing a preference to get used to the minimum and not to move forward, developing fear of change.
- They consider that it is impossible to generate intelligent roads all over the world, being an indicator of the country where they live with inequality.
- Most people make excuses among themselves, showing a lack of importance to the environment because if they see that the place is being polluted with materials such as plastic, coming from packages, groceries among others. They will not see the importance of taking care of the environment or the project itself *saying that if a group of people throw garbage in this place why not them.* - Society does not care about what is external to their country.

Not all the inconvenience of knowing what is the intelligent road is to the lack of interest of the beginning of renewable structures that is directed to the way of thinking of a society, this lack of knowledge is also due to the way it has been reflected in different media or amounts of reports of this generating information.

- The companies in charge of this structure belong to the private sector, making the information of the whole program not visible to the public.

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- This road test has only been implemented as a means of testing in a few countries selected as optimal for testing.
- There is very little information about these technological advances in the web networks, for reasons that recently started and is not allowed to communicate any progress (it is confidential).
- There is no guiding plan of how this road is planned to be structured, only indicating the functions and what energy is going to be used, but no details are known yet.
- The project is launched to the public for 2030, which does not generate urgency of this knowledge, because there are still 10 years to go if there are no delays due to inconveniences.

We can instill to the society that it is an intelligent road by information mechanism, not only present in informative web pages, presenting itself as articles or critical diagnostics because to know about the road, you have to go visualizing its development through the time raised, determining that we are in the XXI century, and everything moves is through social networks, where sales and promotion are not placed in flyers and others, but by advertisements presented in social networks more elapsed, mitigating the lack of interest and through these, the population is more interested in entering the attached web pages.

The intelligent road and its term can lead to what it is and its function, determining that it can be determined by its composition and functionality that it may have over time and raising doubts. The first postulation of this project was raised as a traffic control mechanism indicating the function of preventing accidents such as stalemates product of human error or possibly the deterioration of the roads where the vehicle transcurred, promoting the technology with the purpose that can ensure that response teams such as ambulance, fire, police, among others assisting the injured present taking them to the best possible care. Having priority in their displacements, in such a way that if it is an emergency to reach the destination optimally.

Showing several aspects to have in front of the innovative project of the intelligent road generating a wide knowledge and opportune base, to sustain the viability and possibility of development in each country of the world involving costs and others, in such a way that each governor see the possibility that possesses this new acquisition of intelligent structures, identifying that benefits can acquire its territory.

Construction materials

- Asphalt. It is a kind of viscous bituminous substance or material of black color, constituted mainly by asphaltenes, resins together with oils, used for the manufacture or resistance of these roads.
- Asphalt Cement. Application in heat to this substance, combined with cement, causes consistency and hardness capable of supporting heavyweights.
- Asphalt Emulsion. It is defined as the combination of three main substances: asphalt, water, and a specific amount of an emulsifying agent, which allows the mixing of two substances.
- Asphalt lowered. It is a distinctive material of soft or fluid consistency, whose maximum limit that can be presented in the structures is 300. It is also called cutback asphalt composed or formed of a finely ground mineral, the standard color present is gray, extracted from limestone rocks.
- Rock. It is a substance of primordial characteristic to give a leveling or balance between the road and the subway soil at the level of its structure so that this does not sink or cause unevenness and this structure deteriorates.
- Sand. It is mainly used to compose other substances and to give greater compression or absorption of the unified materials because it is constituted by small grains hardly visible coming from a mineral that is detached from the rocks and accumulated in beaches forming a layer on a land.
- Brick. It is an object made in the shape of a rectangular prism with different functions composed of baked clay, used in the construction of walls, pillars, and roads.
- Sensors. It is a mechanism that is implemented to the intelligent road to meet the needs raised, because it is a device that captures physical magnitudes, highlighting the trajectory of vehicles. This device has the functionality to capture (light variations, temperature, sound, etc.) or other alterations to its environment.
- Batteries. A form of vehicle recharging presentation as an electromagnetic device capable of accumulating electrical energy collected from the sun, to which it is exposed, being able to supply it; it is usually formed by lead plates.
- Solar panels. They are structures mainly for solar energy, which is the one that has the main function of intelligent roads being a device that generates a large amount of heat or electricity. They absorb radiation from the sun thanks to the set of crystals of semiconductor material.

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- Photovoltaic. They are a multitude of cells, called photovoltaic cells, which convert solar radiation into electricity.
- Communicators. They are those who possess a great ability to transmit to others their information by connecting with people or databases, especially the person who has a public activity.
- Reflective paint. The substance of different colors and liquid or thick texture is a demonstration for traffic signs, which energy allows it to renew its luminosity at night.
- Connecting cables. The entire smart highway must be composed of connector cables, either subway or overhead, which are input/output connectors with the functionality of interfaces to connect devices via cables.
- Reinforced plastic. Glass-reinforced plastic, or also being reinforcement for the road component, it is possible to reuse every plastic scrap in a reusable way to create a more rigid layer for greater strength.

The human being as a society will not be so difficult to adapt to these new roads, because today, everything is digital, society is already closely related to all technological mechanisms with various factors to meet the needs requested. We must evolve to adapt to the technological innovations that the automotive sector and transportation systems require, with the vast possibilities that can be generated by providing energy to vehicles because the roads of the future will be intelligent not only because of their ability to communicate with other objects. They are also intelligent because they can supply energy to the vehicles that travel on them.

The intelligent road is being highlighted primarily by the development and interface of various processes that can happen internally in the structure giving us to know that it is the intelligent road, this is called the interaction and automated reaction of electronic components such as wireless sensors, microcontrollers, cameras, engines turn, among others; using an advanced and effective communication to any event occurred. This is formed by points or nodes strategically located in certain sections, with their corresponding protections, which process and transmit information per second in case of accidents of a low, medium, high priority, with cameras monitoring 180 degrees remotely controlled.

To detect an obstacle on the road, the sensor first sends an ultrasound signal at a frequency of 40 kHz, followed by a computer agent, which consists of the report notified by several of these, for this depends on a system where it controls and monitors remotely from the command center.

To control from the web the rotation of several cameras connected simultaneously at 180 degrees, it is done through servomotors where the communication between server and client is linked, this will take connected multiple cameras, to obtain real-time video locally and remotely using a compatible camera, which is connected to the software where it allows the flow of images per second, being captured sequentially in real-time.

When the user enters the website, it is possible to visualize in real-time on a map provided by Google, the administrator can make any change in the control and monitoring system, either by closing or opening a road, each section has an associated sensor which is represented with a green light bulb on the interface that indicates that the section of the road is enabled and red expresses that the road is disabled. In case the user does not know the web portal for consultations, intelligent signage is provided at the beginning of each section of a transit road, to inform the user in advance if the transit road is available or not and in turn, provides information on the optimal route in case one of them presents problems. This signage reacts and updates, with a delay of approximately 12 seconds, after the person who is monitoring the system wants to enable or disable the road that presents some inconvenience.

The idea of implementing a purely informative system on the availability of the different routes in the country in real-time generates satisfaction, reliability, and safety for users when moving from one place to another. The purpose of implementing an intelligent decision-making system on a map is to provide information on the second-best route to take after the main route has had a mishap. Despite the development of new technologies and systems, these cannot decide on any inconvenience presented, for this human interaction is needed, in this case, it was possible to validate the closure or opening of a road through a visual monitoring system controlled from the web.

Illuminated roads

The luminous roads work thanks to a special paint that absorbs sunlight and is released at dusk, with a duration of 10 hours, with this is achieved to illuminate large roads avoiding energy expenditure, while minimizing the supply of electricity, blackouts and is environmentally friendly. Another type of paint acts as a sensor that responds to changes in temperature. It appears invisible when it is hot, but when the temperature drops, it distinguishes itself from the pavement, warning drivers that the surface is icy or slippery.

Work is underway to study the light output required for the signage to be effective in such thick fog. A combined solution to this problem is proposed, using several ideas, on the one hand, to dissipate the fog and, on the other hand, to improve driving safety, where large extractors are provided to

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absorb the water particles from the fog by placing luminous tiles flush with the asphalt through the provision of a small slit.

It is common for some drivers to drastically reduce speed in foggy conditions. Some even stop, causing danger to following vehicles. Therefore, a motion sensor is being designed to detect sudden slowdowns or stops. This will cause the horizontal signage to turn red to warn of the danger of a rear-end collision. In conjunction with this, several intelligent concepts are being developed on the ecological side, such as temperature-sensitive paints that change color to alert drivers when the roads are icy interactive lights that turn on when cars approach and turn down after they pass *wind lights* powered by small windmills that rotate using current from passing vehicles priority lanes that have induction coils for recharging electric cars.

Vehicle infrastructure integration

Vehicle infrastructure integration (VII) is an initiative that fosters research and application development for a range of technologies that directly link road vehicles to their physical environment, primarily to improve road safety. The technology draws from several disciplines, including transportation engineering, electrical engineering, automotive engineering, and computer science. VII specifically covers road transport, although similar technologies are in place or under development for other modes of transportation. Aircraft, for example, use ground beacons for automatic guidance, allowing the autopilot to fly without human intervention. In highway engineering, improving the safety of a road can improve overall efficiency. VII points to improvements in safety and efficiency.

Structural Health Monitoring

Structural health monitoring (SHM) refers to the process of implementing a damage detection and characterization strategy for engineered structures. Here the damage is defined as changes in the material and/or geometric properties of a structural system, including changes in boundary conditions and system connectivity, that adversely affect system performance. The SHM process involves observing a system over time using periodically sampled dynamic response measurements from an array of sensors, extracting damage-sensitive features from these measurements, and statistically analyzing these features to determine the current state of the system's condition.

Intelligent Transportation Systems

An intelligent transportation system (ITS) is an advanced application that, without incorporating intelligence as such, aims to provide innovative services related to different modes of transportation and traffic management and allows users to be better informed and make them safer, more coordinated, and smarter. Use of transport networks.

Photovoltaic pavement

Photovoltaic pavement is a form of pavement that generates electricity by harvesting solar energy with photovoltaic power. Parking lots, walkways, driveways, streets, and highways are all candidate locations where this material could be used. The technology is used in combination with asphalt and can be used on new construction or existing surfaces. The paving material may contain solar panels that are transparent or colored (such as green) to improve aesthetics, sunlight absorption efficiency, and reduce bird hazards.

Conclusion

The intelligent road is destined to be a mechanism with a projection that will change the world, allowing to advance in all the technological aspects present in the mobility located using public or private transport, demonstrating that the society is in constant change looking for constant improvement, where the intelligent road is divided into several types, its function is determined by according to the method that facilitates the population, where it is proposed where its location is exposed, demonstrating that there is not only one type of intelligent road but a diversity, according to the capabilities that present its main operation, lights, recharging, monitoring, Collector, Transmitter, among others.

Smart roads are the arteries of a country, thanks to them, you can mobilize and bring the foreign population to the interior, thus growing trade, this is a drastic change for a society that is increasingly familiar with virtual platforms, but at the time few people know about the subject, for reasons that very little information is present generating ignorance and lack of interest, but this proposal for the year 2030 wherewith certainty will take greater power and will be of global knowledge for acquisition.

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Advantages and disadvantages of the use of self-repairing concrete in Colombia

Ventajas y desventajas del uso del concreto autorreparable en Colombia

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Concrete is one of the most widely used building materials in the world. It is economical, fire-resistant, and malleable, which allows it to adapt to a wide variety of constructions. For this reason, techniques and processes are being sought every day to improve this material so that someday it will not require any type of maintenance and will have a long useful life. Self-repairing concrete or bio-concrete is a material created in the 21st century that can seal the cracks in it, thanks to the fact that it contains certain types of bacteria that allow closing those openings. An investigation is carried out on the impact that the application of self-repairing concrete in Colombia would have in the different fields of construction, using the favorable and unfavorable characteristics that this concrete has, and the results that have been obtained with its use in other countries.

Keywords: Bacteria, Colombia, concrete, research, self-repair

El concreto es uno de los materiales de construcción más utilizado alrededor del mundo. Es económico, resistente al fuego y maleable, lo que le permite adaptarse a gran variedad de construcciones. Por ello, día a día se buscan técnicas y procesos que perfeccionen dicho material de manera que algún día no sea necesario realizarle algún tipo de mantenimiento y tenga una vida útil amplia. El concreto autorreparable o bio-concreto es un material creado en el siglo XXI que tiene la capacidad de sellar las gritas que en él hayan, gracias a que contiene cierto tipo de bacterias que permiten cerrar esas aberturas. Se realiza una investigación sobre el impacto que tendría la aplicación del hormigón autorreparable en Colombia en los distintos campos de la construcción, por medio de las características favorables y desfavorables que tiene este concreto, y los resultados que se han obtenido con su uso en otros países.

Palabras clave: Autorreparación, bacterias, Colombia, concreto, investigación

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Introduction

Concrete is a material used in construction that is a product of a mixture of sand, gravel, and water that is used for the elaboration of various structures such as aqueducts, bridges, and buildings, as it has various properties such as great strength, resistance, and durability that make it one of the fundamental materials for the creation of quality constructions (Beltrán et al., 2013; Kianimehr et al., 2019; Li et al., 2019).

Over the years, the structures of antiquity and the possible materials used in them have been studied, since a large number of them are preserved in good condition despite the hundreds of years they have and the natural phenomena they have had to suffer, and as a result, it has been discovered that concrete is one of those materials that make them up (El-Anwar, 2018; Eryshev, 2019; Menon et al., 2019). However, the conditions and characteristics of factors such as weather and climate have drawn the most attention and, as a result, are the most studied, as they are an important part of the process of improving current concrete and researching and developing different types of it for various conditions that occur on planet Earth.

A team of Dutch scientists from Delft University of Technology, led by microbiologists Henk Jonkers and Eric Schlangen, developed a type of concrete that can self-repair or self-heal due to a component of the mixture that is bacteria with the ability to generate calcium lactate, which can seal cracks and crevices (Morsali et al., 2019; Vijay & Murmu, 2019; Xu et al., 2019).

This innovative material has had a great impact in different parts of the world, so research was conducted to describe the advantages and disadvantages of the application of bio concrete in Colombia because this is a country that needs constructions and buildings made with quality materials since in recent years it has had to see how new and old works that had different purposes and characteristics, collapsed not only because of bad procedures or poor workmanship but because of wear (in the case of the old ones) and because the materials used in them were not appropriate for the terrain, conditions, and ecosystems of the country (Kua et al., 2019; Müller et al., 2019).

A material for the future

Conceptualization

To begin determining which factors make self-repairing concrete a topic of study worth perfecting, it is necessary to understand what processes lead to its creation and which materials compose it; for this, it is critical to define basic concepts that allow understanding the characteristics of this material in a technical and basic manner (Caicedo et al., 2019).

First of all, the idea of self-repairing concrete arose from the need to make concrete in structures more durable and stable, together with the need to reduce costs in the long term in today's different constructions. Concrete has been one of the most versatile materials on the market, and because of this, it has become the most widely used material today, so much so that what we now call metropolises are known, in colloquial terms, as concrete jungles.

To know the importance of this material, it is essential to recognize that this branch of science marked the beginning of an era, which has been different from any other, for its innovation in research and application of lasting technologies. Its birth took place in one of the most important civilizations in evolution, which was responsible for giving humanity treasures such as arches, aqueducts, and well-known cities. The Roman civilization has had a great influence on the research that engineers have developed today, this is because their constructions have managed to overcome barriers such as time and the many adversities they have had to face. These structural gifts that they left hundreds of years ago, are made of a material that has been an element of research for several decades and is known as *opus caementicium*, also called Roman concrete.

Today, concrete does not have the same resistance as the one used for buildings such as the Roman Coliseum and the Temple of Concord, which is still standing after hundreds of years. This situation generated confusion among researchers for many decades, as they could not explain how it was possible that a material discovered hundreds of years ago could surpass today's technological advances. After many years, they finally found an answer to the reason why the type of concrete implemented by the Romans has been so durable and special. been so durable and special. This discovery has brought with it a particular conclusion: the reaction of volcanic rock with salty seawater created a rare mineral called *tobermorite aluminum*.

Self-repairing concrete

The researchers assure that the prolonged exposure of this mineral to saltwater caused a propagation in the concrete fabric, which together with a mineral called *phillipsite*, grew over time, reinforcing the concrete and preventing the appearance of cracks (Mors & Jonkers, 2020). This finding was the trigger that prompted the research of new methods to implement a similar material in buildings since it is not possible to implement a constant application of saltwater in buildings to reinforce the structures to prevent cracking (Fig. 1).

This is the basis of bio-concrete, which is a type of concrete that can self-repair or self-heal, sealing the cracks that form over time and deterioration due to exposure to hostile environmental factors (Beglarigale et al., 2019). self-healing, sealing cracks that form with the passage

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Figure 1

Bioconcrete, self-repairing concrete (Arq, 2020).

Figure 2

Dutch professor creates concrete that repairs itself (Editores, 2020).

of time and deterioration due to exposure to hostile environmental factors.

Bio-concrete began as an experiment at the Technical University of Delft, located in the Netherlands, led by concrete expert Eric Schlangen and microbiologist Henk Jonkers, who developed a revolutionary and innovative material to solve the aforementioned imperfection (Fig. 2).

The solution consists of adding a bacterium called *Bacillus pseudofirmus*, which can last several centuries, as long as it does not come into contact with oxygen. This bacterium consumes some of the aggregates of concrete, which are cement, water, and aggregates, including calcium lactate, the latter is the food that allows the bacteria after its digestion the production of limestone, which upon contact with the humidity of the air increases its dimensions sealing cracks in three weeks (Hong et al., 2019).

Although the process may sound incredible, it has certain limitations that affect its applicability, since its effectiveness is not compromised when the cracking occurs along the length, but if, on the contrary, it occurs with a thickness of more than 0.8 centimeters, this process becomes ineffective.

It is called bio concrete, because the application of organic material, such as bacteria, in construction allows it to be recognized as a biological material since it is alive, which allows the wear and tear of buildings to regenerate. In this sense, buildings and other constructions behave like living beings since they can heal their wounds. That is, strengthen their structure to compensate for the damage caused by wear and tear.

Its use has been tested in countries such as Ecuador, to build irrigation canals, as this is a highly seismic country (Al-Tabbaa et al., 2019). Latin America has been the primary target for the application of this technology due to several factors, including its location in what is known as the Pacific Ring of Fire, which stretches from the coasts of Asia to America and contains the world's highest seismic and volcanic activity. Countries where this belt crosses include Chile, Argentina, Bolivia, Peru, Ecuador, Colombia, Central America, Mexico, and the United States.

One of the most recent investigations of this material has been carried out at the University of Colorado, which proposes a concrete with the same purpose as the Delft researchers, but with a new addition to the mixture, the hydrogel, whose function is to retain water and nutrients to provide a favorable environment for cyanobacteria. This process can be compared to other processes observed in nature, such as the crab that loses a pincer or the lizard that loses its tail, and after a while, they regenerate.

One of the outcomes of the research conducted at the University of Colorado was the creation of a brick made of sand, hydrogel, and bacteria within two hours, after which more quantities of the mentioned materials and nutrients were added, resulting in two bricks after six hours, indicating that the bacteria had done their job.

One of the crucial factors, according to a study conducted on the impact of self-repairing concrete on the road structure, is temperature, as this influences the regeneration period, the cracks did not seal at 4 degrees Celsius, while at 35 degrees Celsius, there was much less sealing than at 23 degrees Celsius. The effect of the bacteria is observed at 23 degrees Celsius because the control specimens did not yield positive results, whereas the specimens with the self-repair agent yielded sealed cracks of up to 0.3 mm (Gonzalez et al., 2018).

Advantages and disadvantages of self-repairing concrete

Concrete fracturing and repair methods

Since the beginning of the use of concrete as a construction material in the main Colombian cities, multiple problems have been encountered as a result of fracturing

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caused by weather and environmental factors. For this reason, research has been carried out in different countries to find a solution to one of the problems, which, as mentioned above, is the fracturing of concrete due to environmental damage, which has caused many structures, already deteriorated, to cause collateral damage in sectors adjacent to their construction.

Concrete is the preferred material used in the construction of buildings worldwide. Large cities or metropolises, as they are also known, are concrete jungles, since all that can be observed is one construction after another, built with different types of concrete treatments, such as reinforced concrete, prestressed concrete, prestressed, post-tensioned, prestressed bonded, or unbonded, interior and exterior prestressing.

The reinforcement in reinforced concrete is an integral part of the section and bears the tensions that the concrete cannot. Steel is a force in prestressed concrete before it is reinforcement. It is load-independent, and if sufficient, the beam behaves elastically under the loads considered. Cracking, in particular, is eliminated without limiting the stresses in the steel, as they developed before the application of the loads. The prestressing steel can, under certain circumstances, function as reinforcement. The treatment that the reinforced concrete receives is the same treatment that the bio concrete receives, that is to say, that the procedures to achieve the expected reinforcement in the concrete, will continue being the same, but, they will have a vital difference, which is the addition of bacteria, that in contact with the humidity of the air, will carry out the process of self-repair of the concrete.

Fractures in concrete can be superficial, of a certain depth, and could even compromise the integrity of the structure, the reasons for this type of situation vary in nature and complexity, among which are: deterioration due to marine conditions, exposure to chemical reactions, affectation by natural phenomena, earthquakes, floods, fires, damage resulting from weathering, erosion, humidity, impacts, wear, displacement or fracture generated by thermal stresses, settlement, shrinkage, overloads, structural deficiencies caused by miscalculation of loads, corrosion of the elements, as well as errors in design and detailing, architectural failures generated by poor construction, the use of inadequate materials and significant neglect associated with supervision and quality control. These situations that generate fracture damage in concrete highlight the importance of generating effective repair methods that act on time.

The methods for the repair of cracks in concrete, taking into account the nature of the affectation, the reform or restoration that can be cosmetic (superficial) or could require the replacement of all or part of the structure, broadly speaking are: the use of epoxy resins, cements grouts, mortars and the use of polymer concrete composites, however, these methods suggest additional expenses in studies and repair materials, which make that if the repair is not carried out in adequate periods, the damage increases and the probability of loss of the structure also increases.

The main characteristic of bio concrete is the structural repair of damages smaller than 0.8 mm wide, in contact with the humidity of the environment and temperatures higher than 4°C, this type of repair could prevent major damages, which would drastically reduce the costs of evaluation and repair materials in a significant way. Especially in Colombia, because the humidity in the environment is quite high, which allows the work developed by the bacteria to be much more effective and better. In addition to the bacteria, the bio concrete contains traditional concrete and calcium lactate, which serves as food for the bacilli for them to produce limestone, a material that regenerates cracks. It is also better than traditional concrete because it doesn't set up too quickly, as it's exposed to air for longer.

The bacteria and calcium lactate in the mixture are in biodegradable plastic capsules that, when cracks appear in the structures, come into contact with water and open, allowing the bacteria to multiply and feed before secreting the limestone that will repair the existing cracks over three weeks. Without the bacteria and calcium lactate, materials expand when wet.

According to research conducted at the Technical University of Delft, the use of this living concrete represents economic savings because there will no longer be a need to repair the structures, as they can do it themselves. In this way, the era of biological constructions will be lived.

Bio concrete background

To provide an adequate value of importance to bio concrete, it is necessary to know what have been the characteristics and results obtained by researchers regarding the benefits brought by the application of this innovative biological technology. The main benefit offered by the application of bio concrete in constructions and buildings at present is self-regeneration, but it is not the only one, it also offers greater resistance to compression, reduction of permeability, among others.

However, the main topic of this article is the benefits offered by self-healing concrete through bacterial encapsulation. The cost of maintaining concrete structures in the United States alone is estimated to be $20 million per year. This statement highlights one of the greatest advantages in the application of bio concrete and that is the budgetary savings offered by bio concrete. The most important factors for promoting the reparative behavior of bacteria are air and humidity. When the crack comes into contact with the environment, bacteria feed on the calcium lactate produced and convert it to calcite, resulting in the crack sealing. This type of bacteria can go dormant for up to

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200 years and reactivate only when necessary (Ponce et al., 2015).

In addition to the self-repair of concrete as a benefit, there is added resistance to situations such as compression. The addition of *Bacillus subtilis* increased the compressive strength of concrete by 14.92 percent, while Bacillus Sphaericus increased the compressive strength of concrete by 30.76 percent at 3 days, 46-15 percent at 7 days, and 32-21 percent at 28 days when compared to conventional concrete.

Mitigating the formation of micro-cracks has become more important than one might think because as a result of these, major damage can form in the structure once the concrete has hardened and is in service. If micro-cracks form in the concrete and water is present, the sleeping bacteria or sporula becomes active. The bacteria, using the calcium source of its food calcium lactate, will act as a nucleation center to precipitate calcium carbonate (CaCO3), which will totally or partially seal the cracks (Guzmán & Ramírez, 2017). Based on this characteristic, it can be affirmed that the creation of cracks that put a structure at risk begins to diminish from the very moment the microcracks are formed, preventing damage that increases with the prolongation of time.

Bacteria are not permanently active, but certain characteristics must be met for them to fulfill their function, once they begin their work, they need food to survive and produce the calcium carbonate that will precipitate in the cracks, that is why to fulfill this function a specific process is fulfilled. To protect the bacteria from crushing and the hostile environment of concrete, they are encapsulated in a porous aggregate, expanded clay. The expanded clay (4-75-1.18 mm) is impregnated with the bacteria solution (12 percent of the clay's weight), yeast extract (5g/l of bacteria solution), and a calcium source, in this case, calcium lactate (200g/l of bacteria solution).

Different variables have been determined that allow demonstrating the importance of research in the application of bacteria in the concrete mix, to create a biological construction material that allows increasing the resistance of the structures and the time that they last, as well as decreasing notoriously the maintenance costs caused by micro-cracking caused by environmental or natural factors. It is important to point out that in developing countries this technology would provide new opportunities in the development of road infrastructure and construction in urban sectors, both in the main cities and in small towns that are in the process of development, since the decrease in maintenance costs allows a small town to improve the quality of its constructions, without worrying about the expense that would represent a study for preventive maintenance, or even a study for an internal repair, adding to this the materials for the concrete repair, through processes that were mentioned above.

It should be noted that access to bio concrete technology is not as utopian as it could be calculated, since the procedure for the creation of concrete would remain the same, but to this must be added the application of bacteria for self-repair in the future.

Bioconcrete in Colombia

Bio concrete as a major player in the road and urban infrastructure development

Bio concrete is a wonderful agent that could generate enormous development in countries whose infrastructure is still in its infancy. That is countries that have been called third world countries because their development has not been so noticeable or accelerated. Bio concrete could mean an opportunity for road constructions and the elevation of buildings to gain strength since one of the major limitations for the construction and application of concrete is the cost of maintenance and repair materials.

The most notorious advantage for which concrete has been called revolutionary has been its self-repairing characteristic, since one of the biggest problems that engineers have had to face is the calculation of the resistance of structures to factors such as humidity, which in the case of self-repairing concrete does not present any threat, on the contrary, it awakens microorganisms that begin to fulfill their function by feeding on calcium lactate and secrete limestone as a result of the process.

Temperature is one of the variables to consider for concrete self-repair because it has been shown that the process is less effective at very low or high temperatures. The cracks were not sealed at 4°C, and there was much less sealing at 35°C than at 23°C, indicating that temperature is an important factor in self-repair. In the case of Colombia, its application would be less disrupted by this factor because, due to its geospatial location, ambient temperatures do not reach the extremes where performance is severely impacted.

The application to road infrastructure would have some limitations because rising temperatures cause a lower rate of repair. At 35°C, the filling was observed in both the control and bacteria specimens, with a maximum thickness of 0-15 mm, indicating that at this temperature, there was an autogenous self-repair effect of the concrete rather than a sealing by the bacteria.

A concurrent problem for the construction of roads in Colombian territory is the variation in the terrain, i.e., the accidentalness of the terrain can cause the concrete to fracture more frequently and easily, so implementing a self-repairing concrete could generate greater benefits than the mechanisms currently used, which are not only expensive but also have a higher fracture rate. The likelihood that road maintenance will be significantly reduced raises the prospect of using bio concrete, not only because of its repair capacity

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but also because it has been demonstrated that the presence of bacteria in concrete improves its resistance.

The majority of repair costs are incurred as a result of cracks that appear during the useful life of the concrete. As a result, having this technology will save you money, time, and inconvenience for the residents of your properties. Although the cost of producing concrete with these characteristics is three times that of standard concrete, this is offset by the avoidance of repair costs due to cracks over time. It is not affected by the chemical composition of rain with a certain degree of acidity; thus, during rainy seasons when there is sufficient concrete-fluid contact time, the water does not penetrate due to the permeability of the concrete (which is a function of the fissures or cracks present). Permeability is reduced in self-repair concrete because cracks are reduced from 0.5 mm to 0.35 mm in width, which is why this type of concrete has better hardening properties than conventional concrete.

Although the application mentioned in the previous section is more focused on building structural constructions, there are also many benefits of self-repairing concrete for road applications. It was previously mentioned that the production cost was slightly higher than normal concrete, but the positive side that this provides is the elimination of unnecessary maintenance, which is used to prevent micro-cracks from becoming a much bigger problem. Bio-concrete has the potential to save billions of dollars in the maintenance of structures such as buildings, bridges, and dams.

The advantages of bio concrete are not limited to the reduction of budgets for maintenance and repair materials; it also provides advantages such as durability and safety, as it has been demonstrated that the useful life of the bacteria mixed with the concrete can last up to 200 years. This type of bacteria can go dormant for up to 200 years and reactivate only when necessary. Because of its thickness, the thermal insulation it provides is greater than that of other materials, allowing for greater temperature stability within the construction and reducing the time it takes for bacteria to repair the concrete.

When cracks appear in buildings made of this material, the bacteria that live within them are exposed to the elements, most notably water. The moisture that enters the cracks awakens the microorganisms, which begin to feed on calcium lactate and secrete limestone as a byproduct of their digestion. This material, among other things, seals cracks in bio-concrete in as little as three weeks.

Despite the benefits that this type of concrete provides, there are some limitations to what it can do. One of the most notable is the way it can repair concrete. Although it is stated that there is no limit to the length of the crack, if it exceeds the allowed width, it will not be able to repair itself. Centimeters to kilometers. However, there is a width restriction: cracks must not be wider than 8 millimeters.

Despite this limitation, it has been demonstrated that bio-concrete offers a novel solution to one of the world's most pressing issues: seismic activity in various parts of the world. Because bio-concrete is more resistant, durable, and has the ability to self-repair due to bacteria, its use could usher in a new era of more durable and welcoming structures. As part of the bio-concrete evaluations, the material was used to construct irrigation canals in Ecuador, a seismically active country. Although it is more expensive than traditional concrete, the cost savings on maintenance are quickly realized.

Finally, it should be noted that rather than disadvantages, bio concrete offers multiple benefits that extend from its application to future times, due to its resistance, self-repair, and durability over time. As highlighted at the beginning of this research, an answer has always been sought to the durability of the constructions that we admire as wonders, since they have been standing for centuries, without the need to replace their parts, which led to finding a compound as complete as the self-repairing concrete.

Its application in Colombia would set a precedent without equal since it would drastically improve the quality of the road infrastructure that is currently in decay and whose sustainability is very high, as well as the application of structures in the urban hull of areas in the growth and cultural and commercial development.

Conclusion

First of all, although bio concrete has a slightly higher price than common concrete, maintenance costs are lower, because due to its ability to seal cracks and fissures that may occur in it, it is not necessary to carry out processes such as welding, injection, or sealing with other materials such as epoxy resins, which will eventually require new maintenance, but the environment itself will be in charge, together with bacteria, of sealing this problem of the structures free of charge.

The environmental impact of this material is great because complementing what was said above about the decrease in maintenance costs, the self-repairing concrete avoids the need for the application of more concrete and cement for repairs so that the production of types of cement in the country could be reduced considerably and likewise the pollution and damage generated by its production in Colombian ecosystems.

Self-repairing concrete is evidence that nature and life will always be indispensable factors in the solution of problems because considering that concrete has bacteria, it could be said that concrete has life and solves its problems with that life.

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And finally, the implementation of this material would prolong the life of the country's constructions and buildings, because it has certain characteristics such as resistance to adverse climates and fire, its flexibility, sustainability, comfort (thermal insulation, better air quality in buildings, and temperature stability) and capacity to acquire an infinite number of forms, in addition to its main capacity for self-repair; thus reinforcing the dream of giving Colombians firm, safe and quality structures.

Taking into account all the factors, characteristics, and conditions of self-repairing concrete and its application in the various fields of civil construction, it can be concluded that there are more advantages than disadvantages of using bio concrete in Colombian constructions, since its economic, social, and environmental benefits are greater than the deficiencies it may present.

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Design of a temperature control system for an egg incubator

Diseño de un sistema de control de temperatura para una incubadora de huevos

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In general, an egg incubator is used to increase the productivity of poultry egg incubation. This tool develops a set of important variables that influence the incubation process for successful hatching, one of these variables is temperature. In order to increase the percentage of hatchability of the system, it is necessary to be able to guarantee temperature stability. This article will address the problem of temperature control in a hen egg incubator, which is key to obtaining baby chicks in optimal conditions. Using the PID control system, the aim is to provide a solution to the temperature variation that occurs in the incubation process. Thus, the purpose of this article is to design a temperature control system based on mathematical calculations using experimental data.

Keywords: Control, eggs, incubator, PID, stability, temperature

En general, una incubadora de huevos se utiliza para aumentar la productividad de la incubación de huevos de aves de corral. Esta herramienta desarrolla un conjunto de variables importantes que influyen en el proceso de incubación para una eclosión exitosa, una de estas variables es la temperatura. Para elevar el porcentaje de incubabilidad del sistema, este requiere poder garantizar una estabilidad en la temperatura. En este artículo se abordará el problema del control de la temperatura en una incubadora de huevos de gallina, que es clave para la obtención de pollos bebé en óptimas condiciones. Utilizando el sistema de control PID se busca aportar una solución a la variación de temperatura que se presenta en el proceso de incubación. Así pues, la finalidad de este artículo es diseñar un sistema de control de temperatura a partir de cálculos matemáticos tomando como base datos experimentales.

Palabras clave: Control, estabilidad, huevos, incubadora, PID, temperatura

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Introduction

The birth and development of the proportional-integral-derivative controller (PID) date back to the period from 1920 to 1940 in the last century, in response to the insistent demands of industrial automation before, during, and particularly after World War II (Han, 2010). In other words, this control system arose from the need to simplify manual control and reduce the errors that occurred in the various industrial processes. Its role in the explosive growth in the post-war manufacturing industry is unmistakable; its mastery is evident even today in several sectors of the entire industry.

The PID controller is widely used in many control applications because of its simplicity and effectiveness (Zhigang Wang & Lu, 2017). Due to this feature, we can say that this is the bread and butter of automatic control. The PID controller is used for a wide range of problems: process control, motor drives, magnetic and optical memories, automotive, flight control, instrumentation, temperature control, etc. (Åström & Hägglund, 2010). These problems can be translated into keeping the variables of a process as close as possible to specified values and keeping the variables of a process within a range (F. Martínez & Acero, 2020).

PID controllers are tools used to exercise control over variables in a process in a system to bring it to a working point, known as a *set point* (Zhenlong Wu & Wang, 2016). To reach this set point, the controller must respond or act quickly to system dynamics, eliminating errors and increasing system stability, resulting in improved performance.

A PID controller is implemented in closed-loop systems thus having a single input (reference variable) and a single output configuration (controlled variable) (Utama & Hari, 2017). The controller must keep the output or response of the system at the set point. When this does not happen and the controller keeps the system output in a range close to the setpoint, errors are introduced in the system response which is corrected by the feedback (Ogata, 1998). Feedback is the comparison between the setpoint which is expected to be the value of the system response and the actual value of the process variable. The loop created by the feedback ensures control over the system by causing the error in the response to be corrected each time the controlled variable is compared to the reference variable until finally the error in the output disappears. As this comparison exists, the process variable will be conditioned by the response of the system. The feedback from the controller is of great importance since it creates the desired behavior in the system resulting in stability.

In a control system, the controller is a device or mechanism that compares the desired output or setpoint of a system with the actual output, and adjusts the input or control signal to the system in order to bring the output closer to the setpoint. This process is known as feedback control.

The feedback from the controller is important because it helps to ensure that the system operates as intended and achieves the desired behavior. Without feedback, the controller would have no way of knowing if the system is performing as desired, and the system may become unstable or drift away from the desired behavior. By continuously comparing the output with the setpoint and adjusting the control signal as needed, the feedback from the controller helps to maintain stability and achieve the desired behavior of the system.

This article will show the steps to develop a suitable temperature control system for an egg incubator using PID controllers.

Problem formulation

The process of incubating hen eggs is an artificial process that simulates the natural conditions of a hen to allow the embryo to develop and reach the chick's hatch. In this process, the temperature is one of the most important factors, since small variations in temperature can be fatal for many embryos. Because of this, the interior of the incubator should provide a constant temperature of 37.5°C.

From this arises the following question How to develop a temperature control system for an egg incubator to maintain a constant temperature, and how to achieve this using the PID control system?

To solve this issue we must take into account aspects such as heat transfer in the egg, which happens when there is a difference in temperature between two regions. Where it is worth noting that the egg allows heat exchange between the interior and exterior of the egg, becoming the means of heat transfer.

Like any material, heat transfer can occur in eggs in three ways. First, conduction, this heat transfer occurs between regions or media that are in contact with each other, from the hottest to the coldest areas. The rate of heat transfer by conduction depends on the temperature difference and the thermal conductivity of these areas (C. Martínez & Josmell, 2015). Therefore, in the egg, heat is transferred by conduction from the embryo to the eggshell, whenever their temperatures are different.

Second, convection occurs when there is heat transfer by air currents and when a body loses heat by conduction (Sharawi, 2013). In that sense, when eggs lose heat by conduction, the air around the eggshell is heated and rises, moving the cooler air near the eggshell to replace the warm air, generating convection currents, which help remove heat from the egg.

Thirdly, radiation, this heat transfer occurs from the surface of a warm body to another one whose temperature is different by emitting heat waves that propagate through

the air (Zhigang Wang & Lu, 2017). According to this thermodynamic principle, the loss or gain of heat in an egg by radiation depends on the difference in temperature between the egg surface and the incubation environment. This means that the best way to ensure the right temperature for incubating the egg is through heat transfer by radiation.

So, with the egg at the correct temperature, the biological process of incubation begins and the embryo starts to grow, then the correct temperature range must be maintained throughout the entire incubation period to achieve a higher rate of hatchability.

Consequently, we can say that the incubation temperature affects the thermoregulatory capacity, hormone levels, and growth rate of the brood. Therefore, the key is to model the temperature of the system properly to achieve the correct temperature in the incubator.

Objective

Design a control system for a hen egg incubator using the PID control system.

Methods

As indicated above, the main objective of this article is the design and development of a temperature control system. To carry out the design, three stages were established in the methodology, which are:

1. Plant system.
2. PID control system.
3. Mathematical models.

Plant system

First, the incubator was built with a closed box made of expanded polystyrene and inside it, a resistor, a temperature sensor, and a fan were placed to guarantee the movement of the hot air inside.

Second, a transient response test was performed by feeding the resistance and measuring the temperature behavior concerning time. From these measurements, a table was made with the data obtained, as shown in Table 1.

Third, we plot the transient response where we get an exponential waveform as shown in Fig. 1.

Fourth, the set point of the egg incubator is set at 37.5°C.

PID control system

Initially, you should know that a PID controller or regulator is a device that allows you to control a closed-loop system so that it reaches the desired output state (Shafiudin & Kholis, 2018). In our case, this controller will allow us to set a constant output temperature of 37.5°C.

Table 1

Transient response values of the egg incubator

Time [m]	Temperature[°C]
0.0	19
2	38.7
4	43.3
6	45.2
7	45.8
10	49.6
13.5	52.6
17.0	56.1
23.5	59.6
30.0	63.1
39.0	64.9
40.0	65.6
50.0	66.4
60.0	67.5
70.0	68.2
80.0	68.4
90.0	68.4
100.0	68.5

As shown in Fig. 2 the PID has three components, which are added together to give the output of the controller. Each one fulfills a certain function and improves a certain part of the response (Ogata, 1998). These functions are:

1. It uses the feedback to reject the disturbances.
2. Eliminates stationary error with integral action.
3. Anticipate the future with derivative action.

Additionally, when the three components of the PID work in the right proportion, we can achieve the expected behavior (Widhiada et al., 2019).

Mathematically, a PID controller has the following formulation:

$$output(t) = K_p e(t) + K_i \int e(t)\, dt + K_d \frac{de(t)}{dt} \qquad (1)$$

Where, K_p is the proportional gain, K_i is the integral time constant and K_d is the derivative time constant.

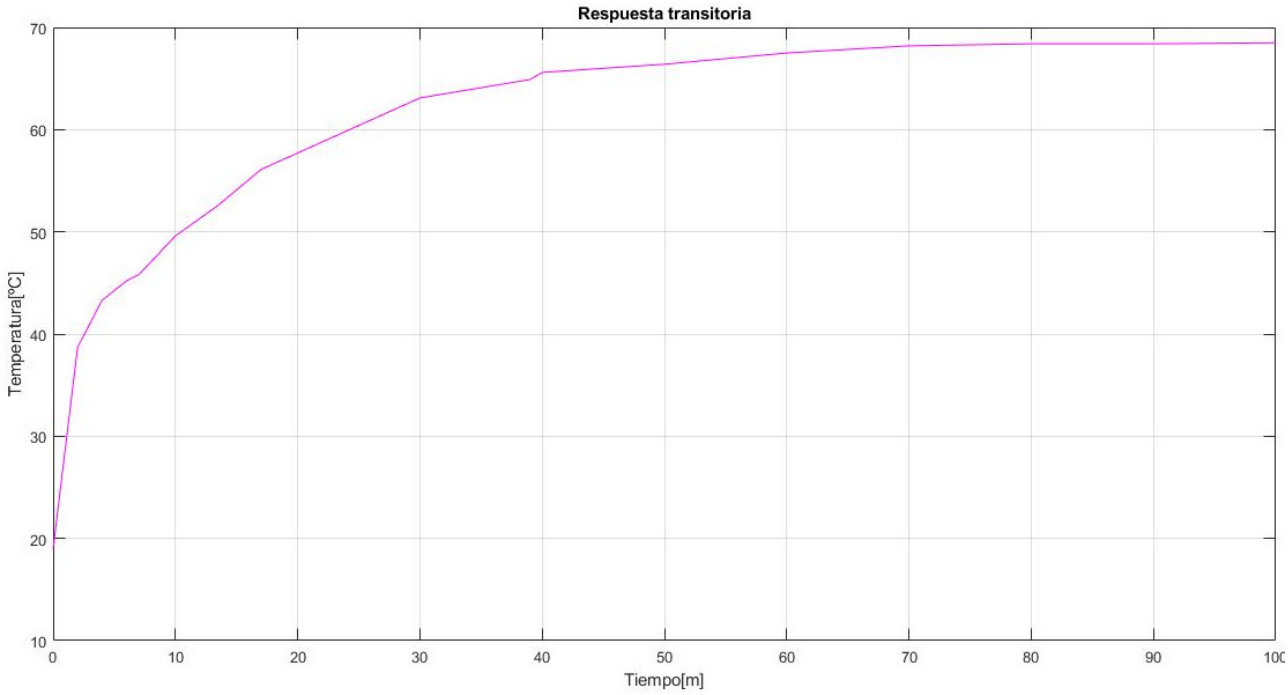
As seen in Eq. (1) each component of the PID is independent of the others, in the sense that each calculates an output of what "for it" should do to obtain the proper response.

That is, the sensor will collect the temperature values obtained indoors, and they will be read by the PID controller and compared at all times to the target temperature which has a value of 37.5°C.

In the PID block diagram, it is observed how the sensor will collect the temperature values obtained inside the plant,

Figure 1

Egg Hatchery transient response graph.



and these will be read by the microcontroller and compared with the target temperature. The transfer function of the PID controller is:

$$G_c(s) = K_p + \frac{K_i}{s} + K_d s \tag{2}$$

Mathematical model

Analyzing the behavior of the transient response curve of the egg incubator, we can say that it has the behavior of a first order system, where the form of its response will be represented by Eq. (3):

$$y(t) = K - Ke^{(-\frac{t}{\tau})} + C \tag{3}$$

Where the initial values are known:

$$t = 0, \quad C = 19 \tag{4}$$

The final condition of the data curve obtained in the laboratory is acquired.

$$t = \infty, \quad y(\infty) = 68.5 \tag{5}$$

Knowing the final and initial condition, the value of K can be calculated:

$$K = 68.5 - 19$$

$$K = 49.5$$

The equation of the system would be as follows:

$$y(t) = 49.5 - 49.5e^{(-\frac{t}{\tau})} + 19 \tag{6}$$

Now the value of τ will be calculated, for this, a linear regression of the function is performed.

$$T(t) = 0.7329t + 20.23 \tag{7}$$

The variable t is cleared:

$$0.7329t = T(t) - 20.23$$

$$t = \frac{T(t) - 20.23}{0.7329} \tag{8}$$

The 63% of the final value of the system function must then be calculated.

$$T = 63\%(68.5)$$

$$T = 31.18$$

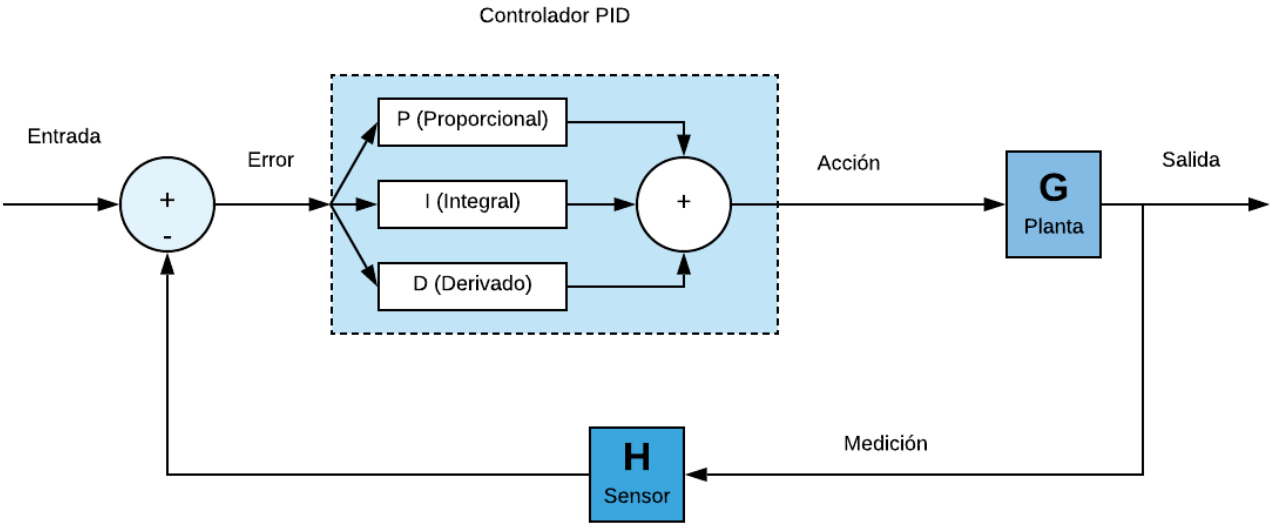
Now the value of τ is obtained:

$$t = 14.940$$

$$\tau \approx 14.940$$

Figure 2

Block diagram of the closed-loop system.



$$y(t) = 49.5 - 49.5e^{(-\frac{t}{14.940})} + 19 \tag{9}$$

$$y(t) = 68.5 - 49.5e^{(-\frac{t}{14.940})} \tag{10}$$

In Fig. 3 a comparison of the curve of the data obtained in the laboratory and the shape of the assumed response can be seen showing that both have a similar shape.

The Laplace transform is then applied to both the input and output in order to know the transfer function.

$$Y(s) = \frac{137}{2s} + \frac{-99}{2(s + \frac{50}{747})} \tag{11}$$

$$Y(s) = \frac{14193s + 3425}{s(747s + 50)} \tag{12}$$

Where its input is a unitary step.

$$u(t) = 1$$

$$U(s) = \frac{1}{s}$$

$$G(S) = \frac{Y(S)}{U(S)} = \frac{14193s + 3425}{747s + 50} \tag{13}$$

$$G(S) = \frac{19(s + 241.316 * 10 - 3)}{s + 66.9344 * 10 - 3} \tag{14}$$

Stability analysis

To determine the stability of the system from its transfer function, the roots of the polynomial of the denominator of the function must be determined and consider whether or not any of these are positive.

$$G(S) = \frac{19(s + 241.316 * 10 - 3)}{s + 66.9344 * 10 - 3} \tag{15}$$

Initially, the values of the coefficients of the denominator of Eq. (15) should be reviewed. Here it is observed that all the coefficients are positive, then, it can be said that the system is stable.

$$P(S) = s + 66.9344 * 10 - 3$$

Analyzing Eq. (15) it can be said that the function has a pole and a zero with the following values (Fig. 4):

$$z = -0.2413$$

$$p = -0.0669$$

Examining the graph in the s-plane it can be confirmed that the pole and zero values are located in the stable zone (Fig. 5). The root locus graph is a graphical representation of the locations of the roots (or zeros) of the closed-loop transfer function of a control system as a function of a design parameter. It is a useful tool for understanding the stability of the system and for designing control systems to meet specific performance requirements. The root locus graph can be used to determine the stability of the system by examining the location of the roots in the complex plane. Roots that are located in the right-half plane (RHP) correspond to unstable

Figure 3

Comparison of the assumed model and curve of the laboratory data.

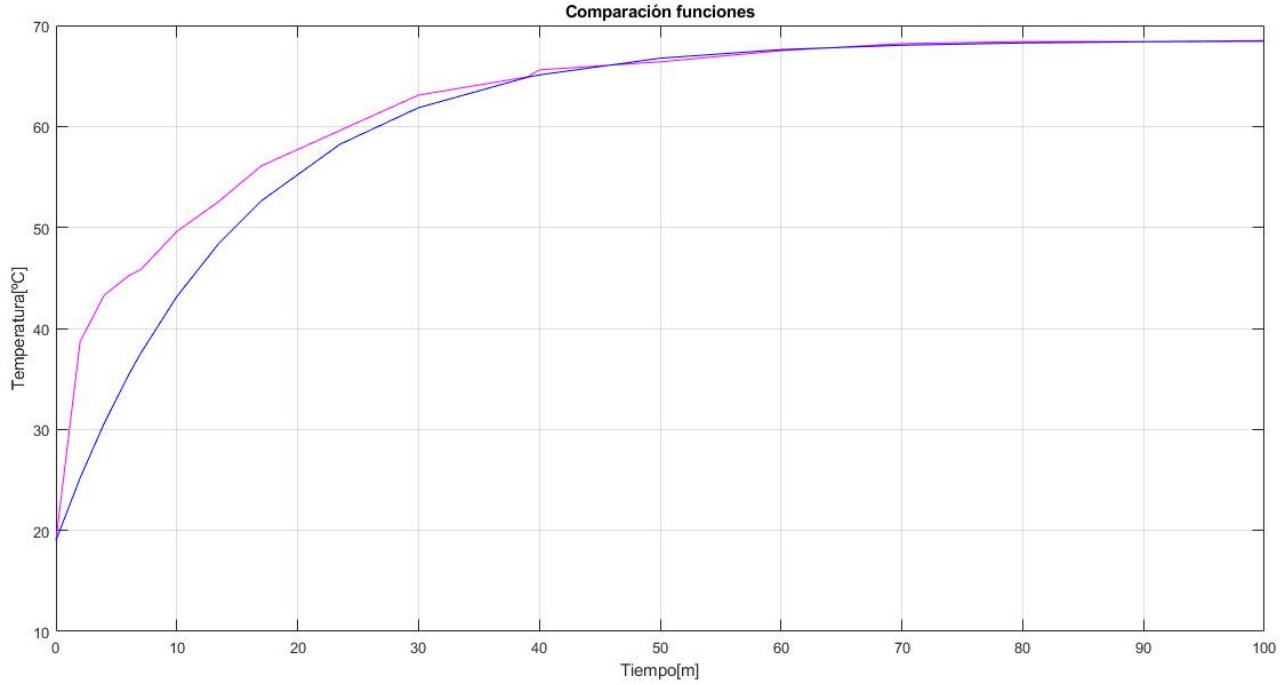


Figure 4

Location of poles and zeros of the transfer function.

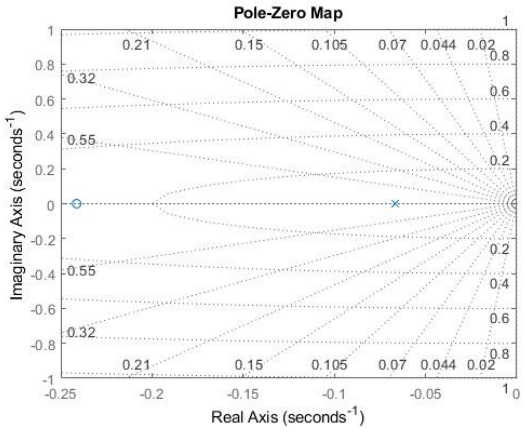
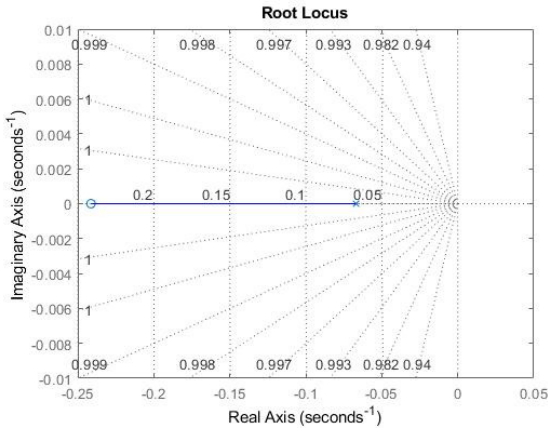


Figure 5

System Root Locus.



poles, while roots that are located in the left-half plane (LHP) correspond to stable poles.

Using the transfer function of the system and with the help of MATLAB, the K_p, K_i and K_d constants of the PID controller were calculated.

$$K_p = 0.015$$

$$K_i = 0.032$$

Where the transfer function of the controller is taken:

$$G_c(s) = 0.015 + \frac{0.032}{s}$$

Results

Although mathematically it is possible to select any gain value for the PID controller, in real life this is not the case;

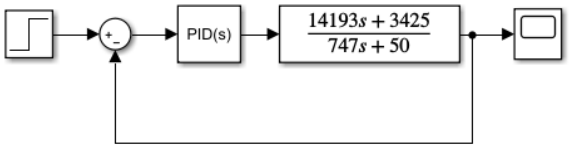
Figure 6

Code in MATLAB.

```
%Calculo de constantes PID
num=[14193 3425];
den=[747 50];
H=tf(num,den)
pidtool %Herramienta para el cálculo
        %de las constantes K_p,K_i y K_d
```

Figure 7

Block algebra graph.



on the contrary, there are limits of all kinds. The root locus graph can be used to predict the response of the system to a disturbance based on the location of the roots. For example, a system with roots that are closer to the imaginary axis will have a faster response to a disturbance than a system with roots that are farther from the axis.

Therefore, in order to verify that the design is physically feasible, the Simulink tool of the Matlab software was used to perform a set of tests to prove the correct operation of the PID controller with the constants previously found with the pidtool of the same software as shown in Fig. 6.

Having obtained the transfer function of the plant and the controller, we will replace the data in the closed-loop block diagram in the Simulink program, as shown in Fig. 7 to obtain the response curve.

The simulations were performed with a unit step input, where an output in the form of a first-order system was obtained as shown in Fig. 8, which is the desired response.

Conclusion

In this article, we present a successful approach for designing and simulating a temperature control system for an egg incubator using a PID (proportional-integral-derivative) controller. We first obtained a data curve of the incubator's temperature over time, which allowed us to identify the system dynamics and model the system as a first-order process. Using this data, we were able to determine the process transfer function, which served as the basis for calculating the PID controller parameters. To optimize the control system's performance, we conducted simulations by varying the PID controller's parameters until we found a set that ensured stable temperature in the incubator. Our findings suggest that the efficiency of the incubation process depends on the effectiveness of the control scheme, which must provide stable and reliable control.

Overall, our results demonstrate that the use of a PID controller is an effective method for achieving temperature stability in an egg incubator. The successful simulation of the temperature control system using a PID controller suggests that this approach could be used in the design of other types of temperature control systems. The importance of temperature stability in the incubation process cannot be overstated, as it plays a critical role in the development and survival of the eggs. Therefore, the implementation of a reliable control scheme like the one presented in this article is crucial for ensuring the success of the incubation process. In conclusion, the development of a temperature control system using a PID controller, as described in this article, can significantly improve the efficiency and success of the incubation process in an egg incubator.

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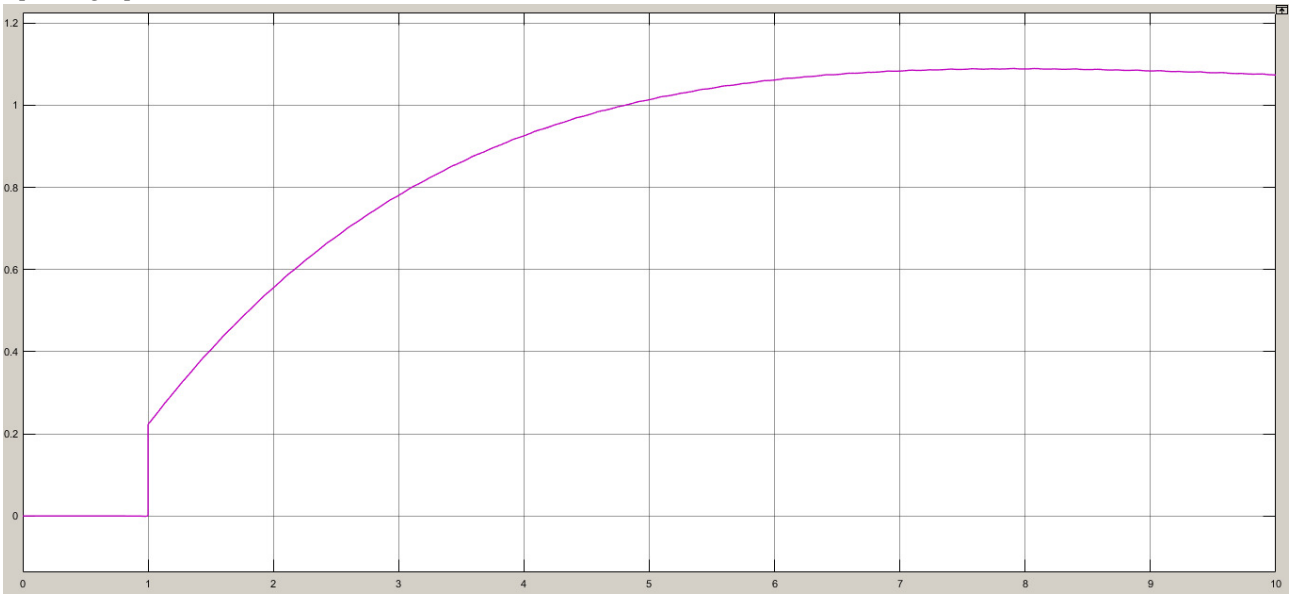
Figure 8

Response graph in Simulink.



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Permeable concrete - water conservation

Concretos permeables - conservación del agua

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The use of pervious concrete in urban mobility infrastructure is analyzed. In addition, its properties are presented, as well as its possible uses and the type of infiltration it can have. The design of pavements presents a divergence condition, it attends to resistance, but not to water preservation. In this sense, research on alternatives that serve as a method of preservation and reuse is presented. The objective is that they not only allow vehicular traffic, but can also transport water internally, and make it reach the desired place. It is concluded that for sustainable and profitable urban mobility, the use of permeable concrete should be an alternative since it meets the requirements of infrastructure, management, and preservation of water resources. Actions are also required to improve and expand the possibilities of using permeable pavements, given some of their limitations.

Keywords: Concrete absorption, infiltration, permeable, pervious concrete, water

Se analiza el uso de los concretos permeables en la infraestructura para la movilidad urbana. Además, se presentan sus propiedades, cuáles podrían ser sus usos, y el tipo de infiltración que puede llegar a tener. El diseño de pavimentos presenta una condición de divergencia, atiende a la resistencia, pero no a la preservación del agua. En este sentido se presenta una investigación sobre alternativas que sirvan como método de preservación y además reutilización. El objetivo es que las mismas no solo permitan el tránsito vehicular, sino que pueda transportar el agua internamente, y hacer que llegue al lugar deseado. Se concluye que para una movilidad urbana sustentable y rentable, la utilización de concretos permeables debe ser una alternativa, ya que atienden a requerimientos de infraestructura, manejo y preservación del recurso agua. También se requieren acciones para mejorar y ampliar las posibilidades de utilización de los pavimentos permeables, dadas sus limitaciones.

Palabras clave: Absorción del concreto, permeable, infiltración, agua

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Introduction

This article aims to research permeable concrete. This can be evidenced in the research of various writers on this topic, which was taken as reference research to determine whether the water that seeps and stagnates in the voids of permeable concrete can somehow be reused, find a way to reuse this liquid would be a breakthrough, especially in the most abandoned and vulnerable areas. Thus we supply more than one need. Among them, we can highlight three, which are:

1. The implementation of functional roads.
2. The supply of drinking water.
3. Avoidance of flooding and, thus, disaster.

The research and writing of this complement very well with the previous background because it meets the conditions where previous concrete should be applied and used, which are areas with little vehicular traffic and areas where there is a lot of rainfall (Lin et al., 2019; Masum & Manzur, 2019; Şengün et al., 2019). In this article, we found a big problem of implementation in vulnerable areas because, in these areas, there needs to be more road maintenance. For this type of case, it is required that there is very great care.

Permeable concrete has the potential to provide multiple benefits in urban road networks, including improved functionality, increased access to clean water, and reduced flooding. However, it is important to carefully consider the limitations of permeable concrete, including its lower strength and higher cost compared to traditional concrete, and to prioritize maintenance and proper implementation in vulnerable areas. Overall, the use of permeable concrete in appropriate situations has the potential to bring significant benefits and should be further explored and researched (Aryan et al., 2019; Kia et al., 2018; Razzaghmanesh & Borst, 2019).

Problem statement

The problem that this article aims to address is how to effectively reuse the water that seeps and stagnates in the voids of permeable concrete, particularly in vulnerable areas where there may be challenges with road maintenance and a need for increased access to clean water. This problem is particularly relevant in areas with little vehicular traffic and high levels of rainfall, where permeable concrete has been identified as a potential solution. However, there are limitations to the use of permeable concrete, including its lower strength and higher cost compared to traditional concrete, that needs to be carefully considered to maximize its benefits and minimize any negative impacts. The goal of this research is to identify strategies for effectively reusing the water captured by permeable concrete in a way that meets the needs of these vulnerable communities and supports the long-term sustainability of their built environment.

Permeable concrete

In road construction, there are two main types of concrete: impermeable concrete, commonly used in highways, roads, streets etc (L.-M. Chen et al., 2019; Rohr-Suchalla & Wolfgramm, 2018). This is characterized by not absorbing water. This is a disadvantage compared to permeable concrete, which can absorb water despite not being used as much. This is because it is a type of concrete with high porosity. This porosity is obtained through a high content of related voids (J. Chen et al., 2019; Kim et al., 2016).

Permeable concrete is generally characterized by having in low quantities fine aggregates. On the contrary, it presents a large amount of cement to cover the particles of coarse aggregates. Performing this action, the concrete can remain firm, and with the voids mentioned above, which are those that allow the absorption of water, which can be recovered, filtered into the drain or stored in the subsoil, the implementation of this concrete is essential in a society as it would be a breakthrough and a great help for sustainable construction (in harmony with the environment). Although it is little used in places such as parking lots, parks, sidewalks and places with little vehicular flow, since one of the most significant drawbacks of this concrete is that it is much more fragile than waterproof concrete, it is recommended to be very clear about the water/cement ratio, because if it has a large percentage of voids, the same water absorption will cause the concrete to begin to crack, on the contrary, if the amount of voids is too small a percentage the concrete will not allow the water to seep enough to be reused.

Permeable concrete properties

It is not possible to speak specifically about fixed properties of this type of concrete since these properties depend on the percentage of voids that are in the mixture, which in turn depend on how it has been treated, the level of cement added, the water/cement ratio, the quality of the aggregates, however, we can say a few observations and recommendations to keep in mind when working with this concrete, One of them and one of the most important is to control the percentage of water that is applied to the mixture since this concrete requires very great precision, to make sure that the mixture is presenting a good water/cement ratio a straightforward experiment that can be performed is to take a little of the mixture and make a sphere if it practically maintains its shape it means that the mixture contains a good amount of water.

As for its effectiveness, although it has been used on many roads in the United States, there needs to be more research to say how efficient it is in using permeable concrete (Sehgal et al., 2018; Wu et al., 2017). Furthermore, concerning the

reuse of absorbed water, it has yet to be discovered precisely how it can be reused since most of it remains stagnant in the pores until it evaporates or seeps into the drainage system or the subsoil.

Uses of permeable concrete

Since the emphasis of this type of concrete is thought in the construction based on the natural water cycle without the appearance of humidity, these concretes can be used in systems such as pavements with minimum traffic, parks, roads, courtyards, among its most common uses are these:

- Parkings
- Cycle paths
- Low water crossings
- Courtyards
- Artificial reefs
- Slope stabilization
- Revetment
- Greenhouse bases/floors
- Hydraulic structures
- Swimming pool covers
- Pavement edge drains
- Noise barriers

Minimal use

The current difficulty in achieving resistance, permeability and reuse of permeable pavements is one of the factors that have caused the use of this concrete to be very minimal. We present some factors that do not favorably help the use of this type of concrete.

Percentage of voids: The percentage of voids will not always be the same for all permeable concretes. This percentage will depend on certain factors such as the compaction of the concrete, the type of aggregates and their quality, and the water/cement ratio, i.e., the moisture content of the mix.

Linear compression: One of the problems in these types of concrete is that the compression is linear concerning the percentage of voids. This means that the higher the percentage of void, the compression that the concrete resists will be lower. This compression can be between 400 psi and 4000 psi, although it is more common to find in these concretes a compression between 600 psi to 1500 psi. Different or opposite case happens in the permeability since the percentage of voids is directly proportional.

Use of additives: Concerning this point, both positive and negative aspects can be presented. One of them is that this type of concrete allows the use of highly polluting additives, such as latex, silica, plastic, fibres or fly ash, without damaging the permeability or resistance of it. On the contrary, it improves the resistance of the concrete. The problem with using this type of additive is that they considerably raise the cost. Therefore, it is necessary to analyze very well in which situations they should be used to keep it manageable.

Aggregate geometry: Maximum size, origin and roughness or shape of the coarse aggregate.

Aggregate dependence: Permeable concrete presents a divergence concerning conventional concrete: the amount of paste used is limited, which is why its strength depends exclusively on the aggregates.

Unlike impermeable concretes, the resistance depends on how the contact between the aggregates is established. Its permeability does not depend on the shape of the aggregate. It will be the same if they are angular or rounded. On the other hand, if you want to gain more resistance, more uniform granulometry and maximum size are used. However, a bit of permeability is lost, but it is not too noticeable.

Water conservation

The main objective of using pervious concrete depends exclusively on water conservation and avoiding disasters or accidents due to excessive rainwater flow. Permeable concrete can let through about 36,000 mm of water/hour.

The proper strength-to-permeability ratio of pervious concrete is directly associated with a water/cement ratio between 0.27 and 0.30. These ratios are too low, so the concrete will have low workability. For this type of concrete, it is required that the paste is not too liquid because it can leak through the ducts where the water is absorbed, generating concrete with a high resistance level but low permeability.

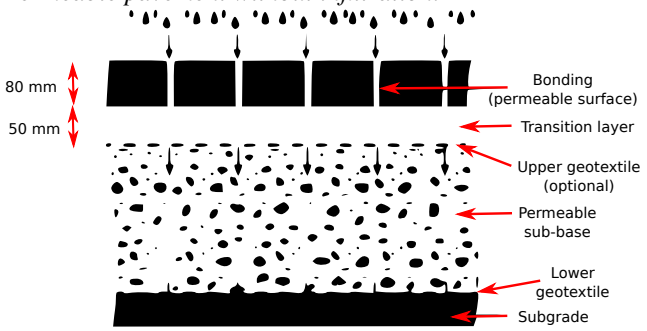
Water conservation can be achieved by different systems, depending on the use and the area where it is located. This depends directly on the following application systems.

No infiltration

Also known as permeable pavements with exfiltration, they are designed to allow water to pass through the surface of the pavement but not to infiltrate into the ground below (Fig. 1). This can be useful in situations where it is not desirable or practical to allow water to infiltrate the ground,

Figure 1

Permeable pavement without infiltration.



such as in areas with high water tables or where the soil is contaminated. Permeable pavements with exfiltration can help conserve water by reducing the amount of stormwater runoff generated during rain events. When it rains on impervious surfaces like traditional pavements, the water cannot soak into the ground and instead runs off into storm drains or other surface water bodies. This can cause flooding and erosion and result in rivers and streams pollution.

Permeable pavements with exfiltration allow water to pass through the pavement's surface and be collected in a subsurface storage system, where it can be treated or reused. This can help reduce the volume of stormwater runoff and prevent flooding and erosion while conserving water resources. However, it's important to note that permeable pavements with exfiltration differ from traditional ones designed to allow water to infiltrate the ground below. While both types of permeable pavements can help manage stormwater and conserve water resources, they work in different ways and are best suited for different applications.

Systems with infiltration

System A - Complete Infiltration: All water penetrates through the surface layer, through the lower courses of the pavement, and into the subgrade. This system does not discharge any water into traditional drainage systems, but some water may be retained within the pavement before it permeates into the subgrade.

System B - Partial Infiltration: The underlying soil provides some level of permeability and infiltration is acceptable. Outlet pipes are installed within the subbase layer to allow excess water that cannot penetrate the existing soil to drain into watercourses, salts, sewers, and so on.

System C - Full Attenuation: This system is typically used where water recycling is required, where water may be contaminated or where the subgrade is impermeable. An impermeable membrane is installed above the subgrade and outlet pipes are installed within the subbase layer. The water can be captured and harvested for use in non-potable applications such as irrigation, toilet flushing, etc.

Absorption capacity of permeable concrete and advantages in vulnerable areas

The first known uses of permeable concrete occurred in Europe in the 19th century. However, its applications grew particularly after the Second World War as a response to the need to rebuild buildings and roads with limited means. The shortage of materials, as well as their high cost and transportation, led to the use of a concrete without fines that reduced the cement (paste) content in the mixes and allowed for the recycling of rubble. Research in Costa Rica on the design of permeable concrete mixes using river and hill aggregates and then subjecting them to uniaxial compression and permeability tests obtained results showing that both properties have an inverse relationship, as generally the variables that positively affect resistance do so negatively with permeability.

Given the above, it is known that this type of concrete should be used in areas with low vehicle traffic and that the few vehicles that flow through these types of roads are of low weight, which is closely related to the objective of this article's research, if it is possible to determine that the water absorbed by permeable concrete can be reused in some way, it could be applied in vulnerable areas and in arid lands where it takes many months to rain, as they would meet the main condition required by permeable concrete by being less traveled. Another advantage of recovering the absorbed water would be the great benefit it would have for the environment.

However, the implementation of permeable concrete in vulnerable areas could also pose a series of problems, because, just as this concrete is very effective in absorbing liquid and retaining it for a long time, it also requires very meticulous care with constant cleaning, otherwise the voids it has will be clogged with dirt, leaving a concrete with the same problems as the waterproof concrete, but with a much lower resistance.

Some research has established the advantages of the use of this technology, in particular, in areas with low vehicle flow it is better to use permeable concrete than traditional concrete, as the latter can bring certain problems to the area. Some of these are:

- When there is too much rain, the water level can rise and cause floods
- The water cannot be properly filtered into the soil, which can cause two problems: first, serious cracking in the concrete due to water getting stuck in the few

voids in the concrete, and second, sinkholes in the roads

- Rainwater cannot be well filtered through the drainage system, so it cannot be treated and the water supply would be much lower. This research also mentions that permeable concrete has been used for more than 100 years.

Already with the above mentioned we can see that the main objective of the research is closely related to the above background because if it is possible to reuse the water absorbed by the permeable concrete, it is appropriate to use it in areas of high rainfall and poor road flow would be perfect for application in villages or sidewalks, the implementation of such concrete would be a great benefit for these populations, They would be roads that due to the type of traffic would last long enough and it would also help for the water supply in this type of areas, especially in areas where the supply is almost null, and there is no access to drinking water, this problem would also be solved because of the voids that the concrete has to filter the water and is stored in these, this water can be somehow reused to supply these areas and to provide a solution to the water shortage in these areas.

There has been quite a lot of research on permeable concrete and how it could be implemented in everyday life, so we could say that there is enough background to be able to carry out the research and answer the question asked.

Some conditions and recommendations to be met by the area where the study can yield better results include the following factors:

- Roads or streets where there is little vehicular traffic. This is to avoid cracking or sinking of the concrete at the time of testing.
- Vulnerable areas with a lack of water. This type of area should be taken into account at the time of the conclusion and results of the experiments since if it is possible to conclude that this water can be reused in some way, it can be used for water supply.
- Areas of high rainfall. The implementation of permeable concrete in this type of area is indispensable because it avoids major flooding and thus the loss of their homes for the families living there, however, being able to reuse the stagnant water in the voids of the concrete would be a great acquisition of this resource that after being treated will be used in the supply of the city or area where this pavement is implemented.

We consider it important to write this article because if we can determine how to reuse the water absorbed by the permeable concrete we can help families, who have almost no access to this vital resource such as water, in their rainy seasons this water can be used to the maximum and thus in times of drought suffer for this resource, also so that in areas where the rainy seasons cause great tragedies, floods can be avoided as much as possible and the stored water can serve as sustenance for this area, that the water can be treated to make it drinkable and achieve a good supply of this vital resource for human life.

How can we ensure that the water absorbed by permeable concrete can be reused?

The mere fact of imagining that there is a possibility of reusing such an important natural resource as water, which to date has claimed the lives of hundreds of people, generates shock, considering that the lack of access to water kills 780,000 people in the world every year, according to a UN report, which highlights the challenge it will pose in the coming years.

Permeable concrete pavements are structures composed of a permeable concrete top layer, a base similar to any other pavement, which in this case can store and manage water, and optionally a drainage system that can be more or less complex depending on the needs, and the natural supporting soil, which can infiltrate water depending on its properties. This type of pavement offers several advantages, such as managing water resources more efficiently, reducing flooding and runoff, improving water quality, and reducing pollutants from entering the groundwater.

What we are looking for is to be able to reuse or give them use to the rainwater of the cities by carrying out different mechanisms that help to collect, conduct and also purify this natural resource in the following way:

Storm sewer system: As is well known, it consists of a network of conduits, catchment structures, and complementary structures. Its objective is the management, control, and conduction of rainwater that falls on the roofs of buildings, streets and avenues, sidewalks, and gardens, among others. So through these, we seek that under each construction of these streets, and roads of permeable concrete there is a storm drainage system so that water absorbed by these can reach a place and can be conducted, and thus avoid problems such as those presented by freezing in cold areas and evaporation in hot areas, likewise risks of loosening and sliding of the earth will be avoided since the absorbed water will have a conductor and its irrigation levels would be greatly reduced.

In the storm sewer system design water filters: The filters are devices made of porous materials and activated carbon; the activated carbon thanks to its chemical properties allows purifying the water, which

would come directly from the pavement. When passing through the filters their job is to retain harmful particles such as rust, iron, mud, and bacteria, among others that can bring the water that at the same time can be harmful to health; these filters help to purify water, and thus to achieve access to drinking water. Although its initial cost may be a little high, its service and as it is projected to the future could bear good fruits, and in such case, it is recovered and would earn much more than what was invested, so therefore it is very feasible to implement and carry out.

Design roads, sewers and filters: These are intended to help convey water to places where there are shortages, as the Colombian Ministry of Housing, City and Territory declared 46 municipalities in a state of public calamity after being affected by water shortages and the drought season in that country. The most worrisome water supply situation is in the department of Bolivar, in northern Colombia, after 37 of its 46 localities were affected. With less than 15 regions with damages, it is followed by Boyacá, Santander, Córdoba, Cundinamarca, La Guajira, Antioquia, Valle del Cauca, Sucre, and Cesar. The state organ indicated that the number of places affected rose from 108 to 114, after the incorporation of the municipalities of Chiquinquirá, Soacha, Cáqueza, Ansermanuevo, La Cumbre, and San Pedro. In this way, each of these 46 municipalities will be reached using the same permeable concrete roads, and their problems will be reduced due to lack of water, which can also be taken and used in places where crops require irrigation systems.

Water reservoir: Water is one of the most precious and at the same time scarce goods. That is why it is of prime necessity to have a water tank that stores this resource in perfect hygienic-sanitary conditions. Water tanks are liquid storage containers that arise as an evolution to all those problems of water supply. Their beginnings started in different fields such as agriculture, livestock, and, of course, personal supply.

Preventing flooding in many parts of the world: Floods are a current problem that has caused thousands of catastrophic events on the roads, and streets, rains have caused thousands of catastrophic accidents thus becoming an imminent danger when it rains and in other cases overflowing rivers that destroy everything in its path. and to this we must add the number of deaths that have been generated, by so many traffic accidents, the permeable concrete could be the most effective solution to this, through the mechanism mentioned above. This is a type of asphalt that absorbs water and, most strikingly, does so in large quantities. With a drainage capacity never seen before, this compound is capable of absorbing no less than 4,000 liters of water in less than a minute.

Hence, their main function is to allow access to water whenever you want, regardless of any supply interruptions that may occur. Water tanks can be installed underground, at ground level, or in some higher areas depending on their use, although the operation is always the same:

1. Water is piped through the utility mains to all properties.
2. Once there, the water is placed in storage tanks such as cisterns and elevated tanks.
3. Finally, the main branch is connected to an endless valve and a float in order to control the water inflow.

In this way, we can conserve the water obtained through the absorption process so that when there is a drought in the country we have that extra resource that can help us to meet some of the needs that we may lack at that time.

Limitations of permeable concrete

Permeable concrete has several limitations that should be considered when determining its suitability for a particular application. Some of these limitations include:

1. Low strength: Permeable concrete typically has lower strength compared to traditional concrete, which can limit its use in applications that require high structural strength, such as bridge decks or heavily trafficked roads. Its use in areas with heavy traffic is very limited, due to its structure and shape, which makes its wear much greater.
2. Freeze-thaw durability: Permeable concrete can be prone to damage from freeze-thaw cycles, especially if it is not properly designed and constructed. This can limit its use in areas with harsh winter climates.
3. They require greater attention and care in the design depending on the type of soil used, such as expansive soils and those susceptible to freezing; although when the water reuse process is carried out, soils susceptible to freezing would disappear.
4. Maintenance: Permeable concrete requires regular maintenance to ensure that it remains effective in capturing and filtering water. This can include regularly cleaning and removing debris from the pores of the concrete, as well as maintaining the surrounding drainage systems.
5. Longer curing time.

6. Sensitivity to water content and control in fresh concrete.

7. Cost: Permeable concrete can be more expensive to produce and install compared to traditional concrete, due to the need for specialized equipment and materials.

8. Limited applications: Permeable concrete is most effective in low-traffic areas and is not suitable for use in high-traffic environments or in areas with heavy loads. It may also not be suitable for use in areas with high water tables or in areas with unstable soils.

9. Considering that these concretes are not very well known, it is foreseen that specialized construction practices will be necessary in order to carry out the procedures and make good use of these concretes.

10. Special attention may be required in cases of elevated groundwater levels.

Conclusion

New technologies make the world evolve day by day, civil engineering cannot be left behind. The needs to create and innovate are increasingly greater, today there are roads, not only with the ability to communicate some places with others but also help to obtain a resource as important as water, it seeks to achieve social, environmental and economic benefits, which can be increased by the use of permeable materials in most urban roads.

Permeable pavements have shown their capacity to avoid undesirable features and events derived from impermeability. Therefore, their use is highly recommended in road networks based on the criteria of water preservation and mobility of people.

Further research should be carried out to learn how to effectively deal with the negative side effects of permeable concretes, in addition to investigating the feasibility of expanding their range of applications through additional research work.

In conclusion, permeable concrete has emerged as a promising solution to address some of the challenges faced by traditional concrete in urban road networks. Its ability to capture and filter water, as well as its potential to reduce flooding and improve water quality, makes it a valuable tool for achieving social, environmental, and economic benefits. While there are limitations to the use of permeable concrete, including its lower strength and higher cost compared to traditional concrete, ongoing research is working to address these issues and expand the range of its applications. Overall, the use of permeable concrete in urban road networks holds great potential for improving the sustainability and resilience of our built environment.

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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.

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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.

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