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Journal of Innovative Engineering

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Knowledge Area

The works must be unpublished and refer to topics of Production systems design, product quality management, operations research, computer simulation, supply chains, quality certification, hydrometeorology and other topics related to Engineering and Technology.

Presentation of Content

In the first article we present, *Mango solar dryer prototype design with temperature and humidity control system with bluetooth monitoring* by Ac-Cauich, Azael Jeremías, Manrique-Ek, Josué Abraham, Cardozo-Aguilar, Guadalupe and Rosado-Pech, Carlos Eduardo with adscription in Instituto Tecnológico Superior de Calkiní and Universidad Autónoma de Campeche, as the next article we present, *In-situ analysis of an intermodular connection for segmented offshore platforms* by Álvarez-Bello Martínez, Rodrigo Daniel, Álvarez-Arellano, Juan Antonio and El-Hamzaoui,Youness with adscription in Universidad Autónoma del Carmen, as the next article we present, *Case study of nutritional supplement for livestock, result of the pecan nut process in the state of Chihuahua, Mexico* by Aguirre-Orozco, Mario Abelardo, Morales-Aguilar, José Socorro, Morales-Chávez, Emmanuel and Contreras-Martínez, Jesús José, with adscription in Tecnológico Nacional de México - Instituto Tecnológico de Delicias, as the last article we present, *Practical guide for assessing the need for conservation or modernization of roads in Mexico* by Gómez-Arizmendi, Gabriela, Rodríguez-González, José Miguel and Bautista-Montes, Luis Pablo, with adscription in Tecnológico Nacional de México - TES Valle de Bravo.

.

Content

Article	Page
Mango solar dryer prototype design with temperature and humidity control system with bluetooth monitoring Ac-Cauich, Azael Jeremías, Manrique-Ek, Josué Abraham, Cardozo-Aguilar, Guadalupe and Rosado-Pech, Carlos Eduardo. *Instituto Tecnológico Superior de Calkiní* *Universidad Autónoma de Campeche*	1-11
In-situ analysis of an intermodular connection for segmented offshore platforms Álvarez-Bello Martínez, Rodrigo Daniel, Álvarez-Arellano, Juan Antonio and El-Hamzaoui,Youness *Universidad Autónoma del Carmen*	12-20
Case study of nutritional supplement for livestock, result of the pecan nut process in the state of Chihuahua, Mexico Aguirre-Orozco, Mario Abelardo, Morales-Aguilar, José Socorro, Morales-Chávez, Emmanuel and Contreras-Martínez, Jesús José *Tecnológico Nacional de México - Instituto Tecnológico de Delicias*	21-28
Practical guide for assessing the need for conservation or modernization of roads in Mexico Gómez-Arizmendi, Gabriela, Rodríguez-González, José Miguel and Bautista-Montes, Luis Pablo *Tecnológico Nacional de México - TES Valle de Bravo*	29-36

Journal of Innovative Engineering December 2024 Vol.8 No.23 1-11
Article

Mango solar dryer prototype design with temperature and humidity control system with bluetooth monitoring

Diseño de prototipo de secador solar de mango con sistema de control de temperatura y humedad con monitoreo vía bluetooth

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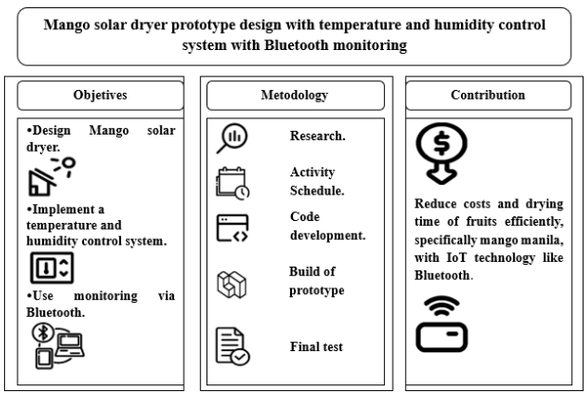
Abstract

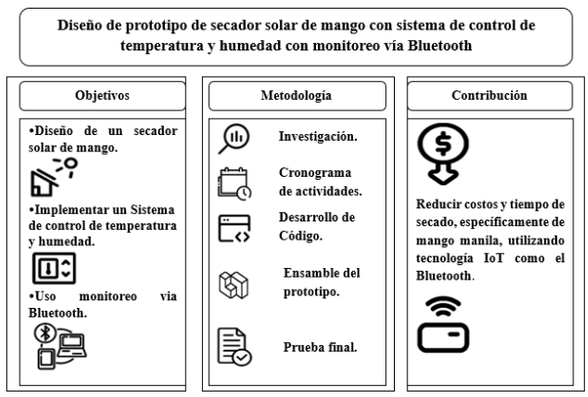
Mango is a fruit that is produced in the southeast of Mexico. To preserve the product, it is necessary to keep it refrigerated and this increases the sales price due to the high electricity consumption. An alternative to taking advantage of this fruit is to dehydrate the pulp, taking advantage of This way the product is not wasted. There are solar dryers where the fruits do not require electrical energy and their conservation is at a very low cost. In this document, the implementation of a project to dry the mango fruit taking advantage of solar energy is presented with evidence so that its temperature and humidity can be monitored via Bluetooth. For this purpose, sensors were adapted with the support of hardware and software. used an Arduino uno board. In the end it is shown that the project has been functional, being an alternative in reducing costs, drying and efficiency.



Arduino Uno, Prototype, Solar dry

Resumen

El mango es un fruto que se produce en el sureste de México, para su conservación del producto se requiere mantenerlo en refrigeración y esto eleva el precio de venta por el alto consumo de electricidad, una alternativa de aprovechar este fruto es deshidratar la pulpa aprovechando de esta manera que el producto no se desperdicie. Existen secadores solares donde los frutos no requieren energía eléctrica y su conservación es a muy bajo coste.En el presente escrito se expone con evidencia la realización de un proyecto para secar el fruto del mango aprovechando la energía solar de forma que pueda ser monitoreado su temperatura y humedad mediante vía Bluetooth" para ello se adaptaron sensores con el apoyo de hardware y software se utilizó una tarjeta Arduino uno. Al final se demuestra que el proyecto ha sido funcional, siendo alternativa en reducir costos, secado y eficiencia.



Arduino Uno, Prototipo, Secador solar

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Journal of Innovative Engineering December 2024 Vol.8 No.23 1-11
Article

Introduction

In the industry the control systems are key, in the performance of this, either translated into performance, efficiency and above all the saving of resources.

In these terms, this paper presents the design ofa prototype of a solar mango dryer with temperature and humidity control system with monitoring via Bluetooth.

Solar dryers consist of two basic elements: the collector, where radiation heats the air, and the drying chamber, where the product is dehydrated by the passing air.

The drying of fruit and vegetables is not a new issue, conventionally they are exposed to the open air on boards, tarpaulins, zinc sheets or stretched on a rope under direct sunlight; however, this method presents several difficulties as they are exposed to dust, insects or other animals that can deteriorate them, thus impacting the quality of the product.

Proposal

To reduce costs and drying time of fruits in an efficient way, specifically of manila mango, is the main objective of setting up a prototype dryer.

Methodology

To begin with, a chronogram of activities was drawn up which defined the steps for the development of the present project.

Box 1

Activities	ACTIVITY SCHEDULE															
	October				November				December				January			
	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4	S1	S2	S3	S4
1.Information collection.																
2.know how the project works.																
3.Compare the design with those on the market.																
4.Obtain characteristics of the models found.																
5.Make a model.																
6.Make a programming code..																
7.Design and assemble the electronic part.																
8.Prototype assembly.																
9.Final tests.																
10.Results.																

Figure 1

Schedule of activities

Source: own elaboration

Research design

The project uses a combination of knowledge of analogue electronics and embedded systems, specifically the Arduino Uno microcontroller. Making use of the sensor data collection processed in the Arduino, packaging the data to display it on the LCD screen locally and also knowing the characteristics of the microcontroller you can add the Bluetooth function by coupling the module of the same, which allows connectivity capabilities to the project, sending data from the Arduino one to a phone, synchronize and observe changes in real time, thus making a local display through a compatible interface with the mobile phone.

Programming

The language used in the code provided is C/C++, which is commonly used in the development of firmware and embedded software for the range of microcontrollers such as the Arduino Uno.

An algorithm was written that can be seen through the link, in order to obtain the functions that are required of the dryer, which consist of the calibration of the sensor, the control of the temperature that is in charge of the drying quality, and the correct reading of the interior of the equipment.

Operation

The process begins by activating the microcontroller, to display the welcome message with the following text SOLAR DRYER (name given), to subsequently display the reading provided by the temperature and humidity sensor DHT11. However, there is a waiting time for the data to be displayed, because it is automatically calibrated in a range of 2 to 50°C in temperature and 20% to 90% humidity. Once the configuration process or set point has been executed within the programme, at this point we must have a space where we can position the prototype dryer and it can receive the heat from the sun by means of the two collectors that have the function of concentrating the thermal energy from the sun, which allows a flow of hot air. Having mentioned this, we are sure that the data measured inside the dryer by the temperature and humidity sensor are as accurate as possible.

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For what continues is that the relays are activated and these in turn the fans, when the system registers a temperature of 45ºC, this activates what is the ventilation in this way circulates a current of hot air inside the cabin, for the part of the humidity, within the programming is that when the system detects a humidity of 90% the ventilation is activated in this way the humidity is controlled inside the same and this slows down the spread of other contaminants that involve the quality of the drying. It continues with the next functionality of the prototype that this can transmit data wirelessly using one of the technologies of the IoT, the Bluetooth protocol, for this, the Bluetooth functionality runs in the background automatically, this is activated in a period of 3s.

Box 2

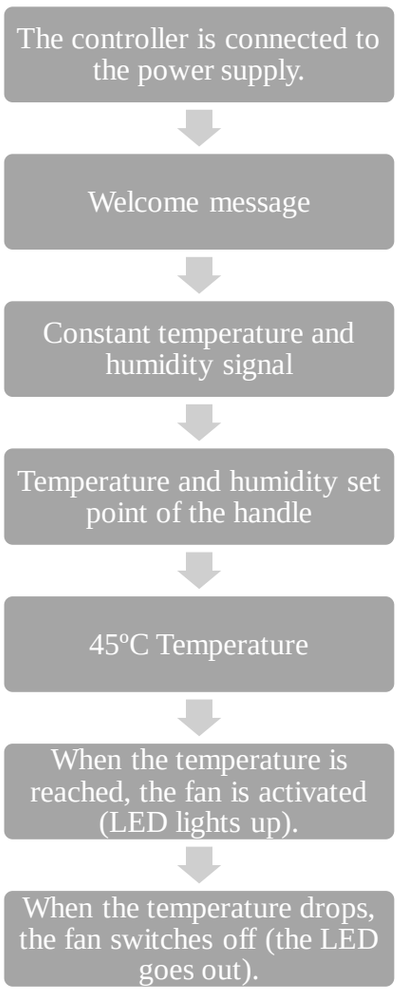

Figure 2

Diagram of the working process of the prototype

Source: own elaboration

It is worth mentioning that the above diagram shows the process in which the LEDs (red and green) are used as status indicators of the power stage, where the activation of the fans takes place.

Design and testing

Once the code shown in the previous section had been created, the next step was to carry out the first tests on a protoboard. To do this, the following circuit was made, including the control and the LCD screen, using the online program Wokwi.

Box 3

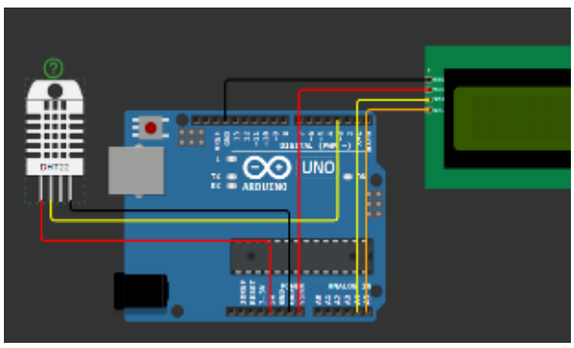

Figure 3

Diagram with sensor and LCD

Source: own elaboration

With the above schematic, the assembly was carried out on a protoboard.

Box 4

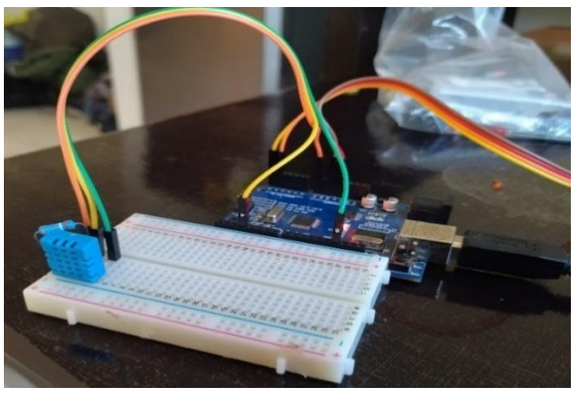

Figure 4

Assembly on the breadboard

Source: own elaboration

ISSN: 2523-6873
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Journal of Innovative Engineering December 2024 Vol.8 No.23 1-11
Article

A test is performed in order to check the status of the LCD display.

Box 5

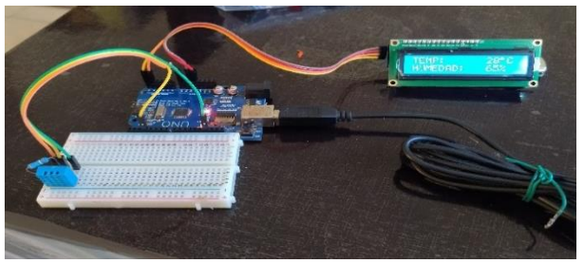

Figure 5
Testing the status of the LCD display
Source: own elaboration

Next, we make the connections of the relay module, which will be responsible for activating the fans.

Box 6

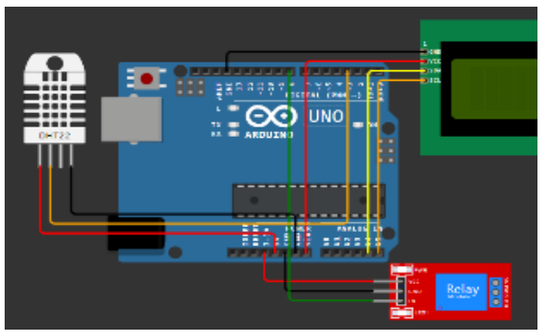

Figure 6
Testing the status of the LCD display
Source: own elaboration

Connections of the relay module, testing of the relay module.

Box 7

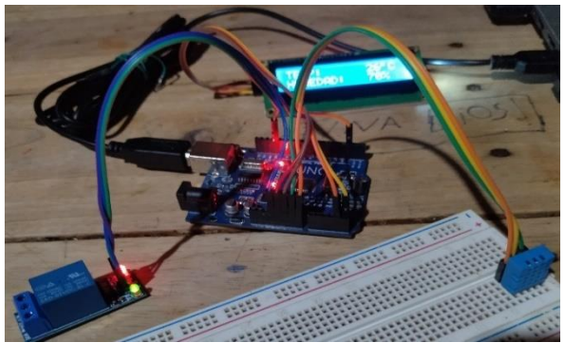

Figure 7
Relay module connections
Source: own elaboration

Moving on, some tests are then carried out with the sensor.

Box 8

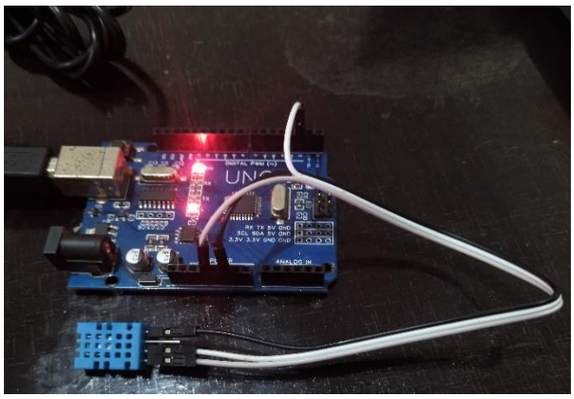

Figure 8
Testing with the sensor
Source: own elaboration

Temperature and humidity measurements.

Box 9

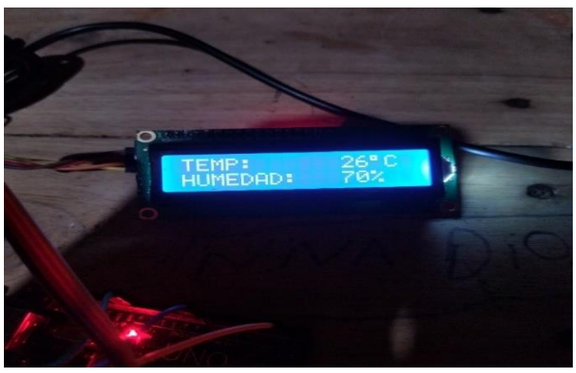

Figure 9
Taking temperature and humidity measurements
Source: own elaboration

Once this has been done, we have a diagram that includes the connections of all the electronic components.

Subsequently we made a diagram that includes the rest of the components to be used, such as the fan, the bluetooth module, the relay together with the connection diagram of the Arduino one microcontroller previously elaborated. To do this, a link is attached where the schematics and diagrams that were developed are presented, in addition to finding the code in text format.

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Now some tests were made to verify correctly the function of the relay according to the change of humidity that we declared in the programming, for it, images are attached, figure 10, 11 and 12, where we observe the change in the relay module.

Box 10

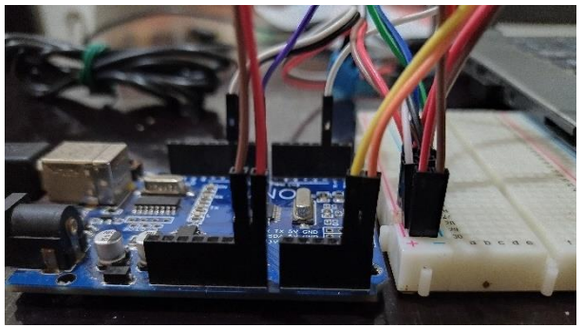

Figure 10

Connection of the components to the Arduino

Source: own elaboration

Box 11

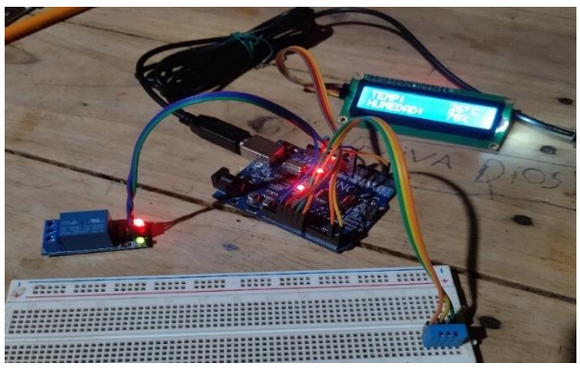

Figure 11

Testing the change of state of the relay in relation to humidity

Source: own elaboration

Box 12

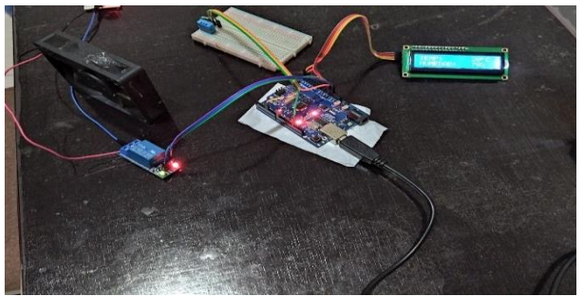

Figure 12

The relay is activated when there is considerable humidity of 70%

Source: own elaboration

Power supply

For the ventilation system, a separate power supply was required to supply the demand of the fans, consisting of a linear power supply, transformer, bridge rectifier, and the calculation of the capacitor. to design the diagram figure 13, one was made from a software, Multisim was used.

Box 13

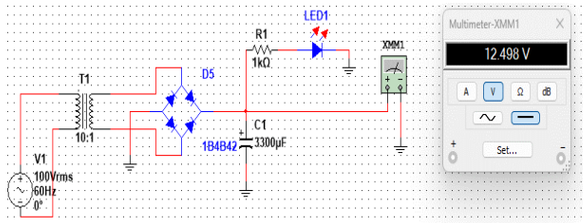

Figure13

Linear source diagram design in Multisim

Source: own elaboration

Now that we have the design, we move on to the assembly of the components of the source on a perforated plate. But, before starting with the assembly, it is necessary to calculate the value of the capacitance, which is needed in the rectifier to correct the ripple of the diode bridge rectifier, the procedure that was carried out is shown in a simple way:

- Identify the transformer parameters.
- The voltage drop of the diodes.
- Use the capacitance calculation formula.
- Approximate the value obtained from the formula with the commercial values available.

With this description of the simplified steps to obtain the value of the capacitor, the following operation is presented:

Calculation of capacitor of the voltage source for the power stages

Transformer characteristics:
Voltage range: 110 ~ 127 vac
Voltage output: 9 vac (unrectified).
Transformer current: 500mA - 0.5A.
For the calculation of the capacitor the following formula is used:

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

Journal of Innovative Engineering December 2024 Vol.8 No.23 1-11
Article

$$C = \frac{I}{2 \times F \times v_r}$$

I = current.
F = AC frequency.
Vr = percentage voltage variation.

Therefore:
Vp = 9 x $\sqrt{2}$ = 12.7279v

Considering a variation of 10 %:
Vr = 12.7279 x 10% = 1.27279

The following is then carried out:
$C = \frac{I}{2 \times F \times v_r} = \frac{0.5A}{2 \times 60Hz \times 1.27279v} = \frac{0.5A}{152.7348v} =$ 0.003273648
C=3,273.48 x 10^{-06} µf
C=3,273.48 µf

Closest commercial value is: 3300µf for the bridge rectifier.

Box 14

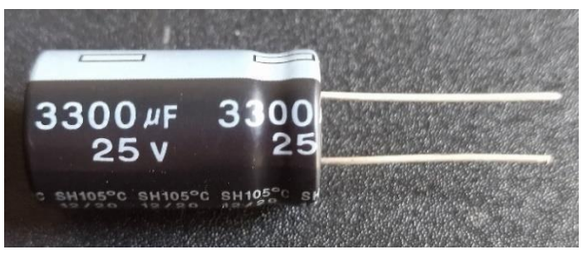

Figure 14
Required capacitor value according to the transformer parameters and the formula used
Source: own elaboration

The assembly of all the components on the perforated board is shown below, it is worth mentioning that a red LED indicator is implemented to indicate the function of the power supply.

Box 15

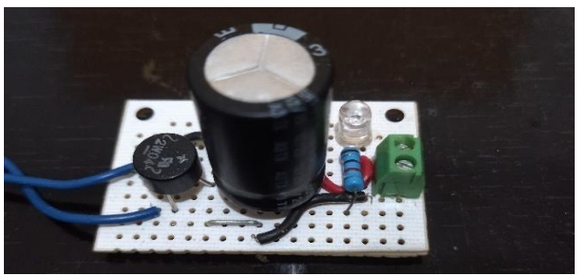

Figure 15
Assembly of the components on the perforated plate
Source: own elaboration

Indicator led test.

Box 16

Figure 16
Test of the source, and the indicator led
Source: own elaboration

Now you can see the assembly of the line source including the transformer.

Box 17

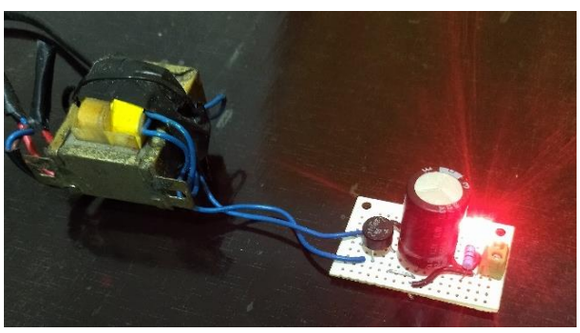

Figure 17
Final result of the linear source
Source: own elaboration

The next step was to make the design, figure 18, of the model of the drying cabinet and the collectors in SOLIDWORKS.

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RENIECYT-CONAHCYT: 1702902

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https://doi.org/10.35429/JIE.2024.23.8.1.11

Box 18

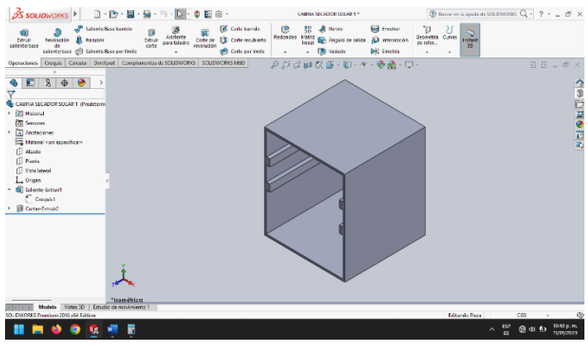

Figure 18

Design of the model of the dryer cabin

Source: own design

The design of the collector is presente.

Box 19

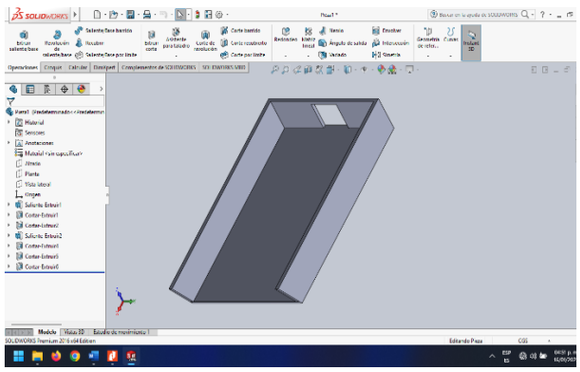

Figure 19

Design of the collector model for the dryer

Source: own elaboration

Following the procedure, the assembly of the cabin was carried out, as well as the installation of the collectors and the drying meshes.

Box 20

Figure 20

Assembly of the drying cabin

Source: own elaboration

Then assembly of collectors and meshes.

Box 21

Figure 21

Assembly of the collectors to the drying cabinet, and the installation of the nets

Source: own elaboration

Continuing with the control part, the installation of the electronic system is carried out, which is in charge of automating the dryer. A space was designed for all the electronics, installed in the wooden material that is the structure of the dryer.

Box 22

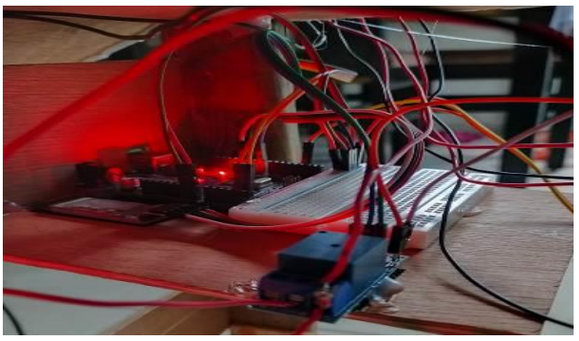

Figure 22

Installation of the electronics, which corresponds to the control system

Source: own elaboration

In the same way, the LCD screen was installed, using wooden material for it, as well as the indicator LEDs.

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

Ac-Cauich, Azael Jeremías, Manrique-Ek, Josué Abraham, Cardozo-Aguilar, Guadalupe and Rosado-Pech, Carlos Eduardo. Mango solar dryer prototype design with temperature and humidity control system with bluetooth monitoring. Journal of Innovative Engineering. 2024. 8-23:1-11
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Journal of Innovative Engineering December 2024 Vol.8 No.23 1-11
Article

Box 23

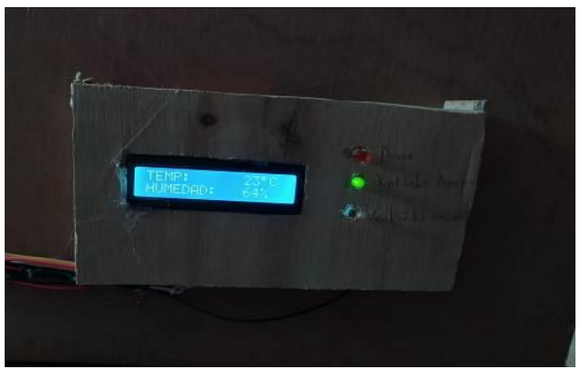

Figure 23

Assembly of the LCD display, and the indicator LEDs Source: own design

Box 24

Figure 24

Assembly of the LCD display, and the indicator LEDs

Source: own elaboration

Checking the drying quality (see annexes 1 and 2 of the initial state of manila mangoes and weight).

Box 25

Figure 25

The prototype has proven to work, with drying, a portion of mango manila

Source: own elaboration

Results

One of the objectives of the work is that it was carried out thinking of a process by which the drying of the mango is efficient and without the need for the intervention of an operator who is continuously observing the process, in addition to the use of renewable energies such as solar energy, thus reducing production costs and, hand in hand, care for the environment. By using easily accessible materials, it supports small producers to obtain it, helping in this way in the conservation of their fruits, specifically the manila mango for their self-sufficiency or as an alternative production and trade. As well as implementing wireless communication technologies, the IoT, such as the bluetooth connection protocol. I consider that the objective has been achieved, because, as we saw previously, different electrical diagrams and diagrams were drawn up and used in this control. During the course of working on the project it was possible to develop a program for the microcontroller, which is the aim of developing an efficient program for the Arduino Uno. Without a doubt this point was a success, as we were able to realise the program on an Arduino Uno, giving us fast read and response times.

One of the most important challenges was the development of the program, since the objective is that the program is not too complex and is effective, that it correctly performs the control that is necessary to comply with the quality of the drying of the mango.

This work is presented as a prototype for the use of the manila mango harvest, as for a dryer, giving an added value to the automation that allows control by feedback.

Conclusions

Based on the main objective of the project 'Design of a prototype of a solar mango dryer with temperature and humidity control system with monitoring via Bluetooth', I can conclude that I have fulfilled it successfully, since we have respected the deadline that was intended from the beginning, doing each of the tasks that were required in the control.

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https://doi.org/10.35429/JIE.2024.23.8.1.11

A functional prototype of the control was obtained with the aim of having an alternative with similar efficiency to the controls already in use, with much lower costs and with the benefit that it can now be manufactured, with the different schemes that were developed in the process, the list of materials required and the programming done exclusively for this project.
Technology nowadays gives us many possibilities to carry out projects, and although I was limited in certain things by the availability and time at some points in the process, the project could be done without so many complications. However, I consider it necessary to mention a series of recommendations that could make this project a lot better.

- The idea was to set a deadline of 4 months to create this control, because for the professional residency it takes about 500 hours divided into 4 months, which did not allow me to finish perfecting or testing the device. So, clearly, with a little more time, it is certainly possible to obtain a control that is even more efficient and with the guarantee that there are few faults that could occur, with a better design, and even adding more functions to the programming.

- It is proposed to add buttons or push buttons on the control part, to change the bluetooth status, i.e. to install a button that when pressed activates the bluetooth and when pressed again deactivates it, so that when monitoring by mobile phone is necessary, it has the option of activating or deactivating it.

- It is proposed to install three sensors in different parts of the dehydrator so that the system can be monitored in the different parts of the dryer.

- Some of the materials used for this project were reused, as they were components that had been available for disposal for a long time. Some of them showed wear and tear due to environmental factors. All this leads me to think that by using brand new components, we were able to avoid certain problems, facilitating the soldering process on some components.

- I was able to get a program that can synchronise with the phone, which allows me to visualise the data sent from the microcontroller via a graphical interface. That's why I think that with more time and more tests, we can add functions depending only on the control.

- The assemblies of some components were mounted with perforated phenolic plates, taking into account the low complexity of the circuit, it is worth mentioning that with time and funding we would have a professional and aesthetic finish.

Annexes

Annex 1. Initial state of manila mango and weight.

Annex 2. Initial weight of mango.

ISSN: 2523-6873
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Statements

Conflict of interest

The authors explicitly declare that they have no conflict of interest related to the research presented in this article. There are no competing financial interests or known personal relationships that could have influenced the objectivity, integrity or interpretation of the results and conclusions presented in this paper. This statement confirms the authors' transparency and impartiality in communicating the research findings.

Authors' contribution

Principal Investigator

Ac-Cauich, Azael Jeremias: Definition of Objectives: Defining the objectives that are intended at the beginning and the scope of the project of a system that is specific in the Design of Prototype Solar Mango Dryer with Temperature and Humidity Control System with Monitoring via Bluetooth. Project Management: Manage the different activities, processes, assignment of work and the registration of the correct development of the project as established (time and form). Circuit Design: In charge of the development of all electrical and electronic circuits, as well as the programming of the microcontroller.

Manrique-Ek, Josué Abraham: Drafting and Documentation: Responsible for all documents necessary to support the project by means of evidence and development proposals. Coordination of documentation and project development: Responsible for the revision of all the bibliographic material used, as well as the supervision of the documents requested and the progress of the project.

Cardozo-Aguilar, Guadalupe: Project supervision: In charge of verifying the correct functioning of the project, complying with the specifications that were requested. Review of electrical diagrams: Gives the go-ahead to the different diagrams and diagrams where the connections of the device are shown, validating them for their implementation and exposure in the documentation.

Rosado-Pech, Carlos Eduardo: Validation of results: Checks and determines satisfactory results of the project, complying with the established objectives. Drafting of conclusions and recommendations: In charge of analysing the results for the generation of conclusions, highlighting possible fields of improvement in the project.

Availability of data and materials

Data generated during this research will be [available upon request / deposited in a public repository / shared with interested parties]. Access to data will be granted in accordance with ethical considerations, privacy regulations and any relevant institutional or legal restrictions.

Funding

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Abbreviations

1. LCD: acronym for Liquid Crystal Display, which in Spanish means ‘Pantalla de Cristal Líquido’.

2. IoT: stands for Internet of Things, which in Spanish translates as Internet of Things.

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Journal of Innovative Engineering December 2024 Vol.8 No.23 12-20
Article

In-situ analysis of an intermodular connection for segmented offshore platforms

Análisis en sitio de una conexión intermodular para plataformas marinas en segmento

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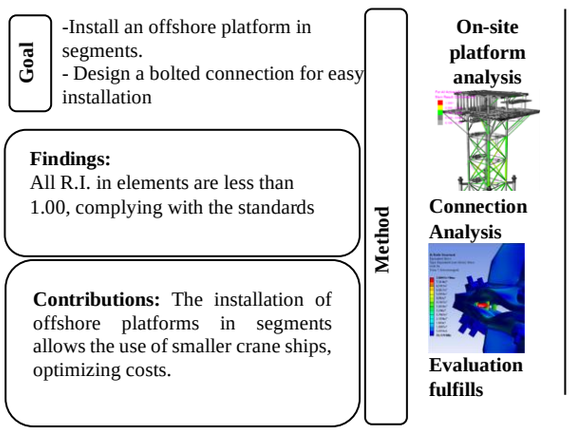
Abstract

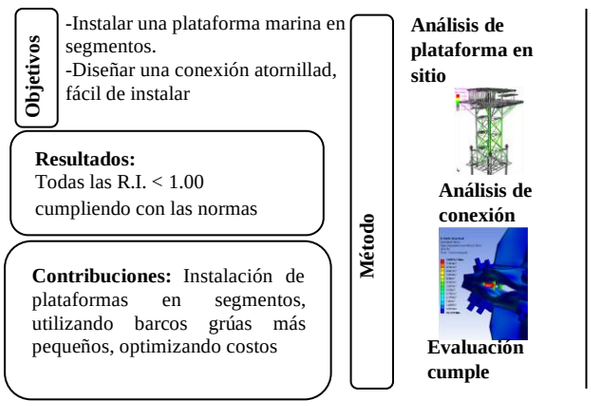
In recent years, oil production in the México has decreased. As a result, there is a need for the installation of new offshore platforms, both in currently exploited fields and in future fields. Consequently, it is necessary to design, construct, and install platforms that optimize costs and reduce construction and installation times. To address this, the proposal involves the installation of these structures in segments, with connections made using bolted joint connections that are secure under in situ loading conditions. Under these loading conditions, analysis is conducted through finite element modeling, demonstrating appropriate behavior according to the requirements of current regulations. The implementation of this solution offers an alternative for the installation of offshore platforms, which largely depend on the availability of installation equipment with capacities exceeding 800 tons



Structure, variations, adjustments, region, prototype

Resumen

En los últimos años se ha reducido la producción de petrolera en México. Debido a esto, se requiere la instalación de nuevas plataformas marinas, tanto en los yacimientos que se tienen en explotación, como en futuros campos, por lo cual, surge la necesidad diseñar, construir e instalar, plataformas que optimicen los costos y reduzcan sus tiempos de construcción e instalación. Por tal motivo, se propone la instalación de estas estructuras en segmentos, realizando la unión entre ellas considerando conexiones atornilladas que sean seguras bajo las condiciones de cargas in situ. Bajo estas condiciones de carga, se realiza en análisis mediante modelado por elemento finito, observándose comportamiento adecuado bajo los requisitos considerados en la normatividad vigente. La implementación de esta solución permitirá disponer de alternativa respecto a la instalación de plataformas marinas las cuales dependen en gran parte de la disponibilidad de equipos de instalación con capacidades mayores a 800 toneladas.



Estructura, variaciones, ajustes, región, prototipo

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Journal of Innovative Engineering December 2024 Vol.8 No.23 12-20
Article

Introduction

Mexico is a world oil producing country, with a daily oil production in April 2024 of 1,784.0 thousand barrels according to oil statistics reported in PEMEX (2024).

In recent years there has been a drop in oil production. Due to this, the Mexican government has allocated larger budgets to invest in order to increase production in the coming years, which requires the installation of new offshore platforms, both in the fields that are currently being exploited and in future fields, which is why there is a need to design, build and install platforms that optimise costs and reduce construction and installation times.

The installation of substructures (jacket) and superstructures (topside) of offshore platforms is carried out by means of two main manoeuvres, lifting or launching, as shown in Figure 1.

Box 1

Figure 1
Lifting and launching manoeuvre

Marine structures type ELM (light offshore structures) tetrapods, for stays greater than 30.0 meters have weights greater than 800 ton and superstructures (topside) tetrapods of two levels, have weights greater than 800 ton, this weight has to be multiplied by the dynamic amplification factors of 1. 40 established in the PEMEX specification ETP-041 (PEMEX, 2014) resulting in weights of 1,120 ton (800 ton x 1.40 = 1,120 ton), for which large crane ships have to be used, which represents a high cost.

In the historical context, offshore bolted connections have been used for more than 20 years in the industry, some application cases are for the installation of risers, jetties, and well attachments as shown in Figure 2 for the installation of the second MALOOB-B drilling rig attachment.

Offshore connections are of great importance for metallic structures, due to the above, several studies have been carried out in which the behaviour of the connections under different load stresses have been analysed, these studies will serve as a basis to observe the considerations, methodology and results.

In relation to the development of intermodular connections, it was found in the literature, the scientific development of these mainly for mid-rise buildings, as reported by several authors such as Ferdous et al. (2019), Sriskanthan et al. (2020), Dai et al. (2020), Lacely et al. (2021) and Chen et al. (2023). Applications related to offshore platforms, reported by Lotsberg (2019), are related to the connection of foundation piles and superstructures, which have been implemented solutions for several decades. In the following, relevant aspects identified will be discussed.

According to Ferdous et al. (2019), modular construction offers faster and safer fabrication, better estimation in completion time, quality of work, fewer workers on site, less waste of resources and a more environmentally friendly solution compared to the conventional construction process. However, despite having several advantages, the private sector still relies heavily on the traditional on-site construction method. Essentially, modular buildings are widely used in low-rise buildings and have shown great interest for multi-storey building structures. Prefabricated modules, as one of the options, have demonstrated satisfactory performance under static loads, dynamic impacts, cyclic loads, seismic, blast, fire and long-term sustained loads, as well as offering environmental, economic and social benefits.

The acceptance and application of modular construction will expand with the development of design procedures, trained workers, the solution of lifting and transportation problems, and the development of new connections between modules.

This study identified the lack of design guidelines due to conflicts with traditional design processes, lack of skilled labour, difficulties in transportation, lack of adequate connections between modules and high initial costs.

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Journal of Innovative Engineering December 2024 Vol.8 No.23 12-20
Article

Some solutions for platform connections are reported by Lotsberg (2019), which consist of grouted connections that are used in various types of structures. These connections are structural joints where a filler material, commonly a mixture of cement and other materials, is implemented to fill the space between two structural components. This provides additional bonding and strength to the connection. When applied to the pile-substructure connection of a platform, jackets are placed around the pile and filled with grout to secure the structural connection and provide additional stability. Based on laboratory tests and experience with different types of connections, the researchers observed that the actual behaviour of the connection depends on the structural geometry and the type of loading. Therefore, different design methodologies are required for modular connections.

Sriskanthan et al. (2020) report that modular construction in buildings has been promoted, identifying technical, logistical and regulatory challenges, especially in terms of achieving efficient lateral load transfer and intermodular connectivity. Efficient resistance to lateral loads requires the formation of vertically and horizontally continuous and rigid structural systems. Stiff diaphragm assumptions must be carefully evaluated because, if the connections between modules are not able to provide the necessary stiffness, out-of-phase movements and module displacements due to gravity could destabilise and potentially lead to the collapse of the modules. Dai et al. (2020) investigated the axial load resistance of connections with shear and grout connectors implemented in modular construction. The researchers identified that, under this loading condition, the connection can be characterised through sliding load and peak load. In the studies conducted, they evaluated key parameters such as the number of shear connectors, spacing between them, grout strength and grout thickness. They identified that, to improve efficiency and strength, shear connectors can be placed. It was observed that, under axial loading, the grout is locally crushed near the shear connectors and diagonal cracks propagate from the connectors of the inner tube to the inner surface of the outer tube of the connection. Also, as part of the failure mechanism, the compression struts resist axial loading until crushing of the grout section is reached.

Subsequently, Lacely et al. (2021), carried out numerical studies to investigate the variables considered in the experimental model of a modular interconnection, where the shear effect, axial load and moment-rotation were mainly evaluated. This, considering simplified empirical and analytical models to predict the structural behaviour of intermodular connections. The purpose of the study was to propose expressions for practical application in modular building interconnections.

More recently, Yang et al. (2023) describe the mechanical behaviour of intermodular connections and assembled joints in modular steel buildings. The authors also address the study of connections in buildings, focusing on mechanical performance, innovative connection types and areas of research. The authors' research mentions that bolted connections are common, but have limitations, which has led to the exploration of new connection types or improvements such as post-tensioned and prestressed connections.

Tung (2024), conducted a study simulating a modular construction under Mars conditions. The researcher highlights the importance of the modular construction method, which would allow the design and construction of the modules on planet Earth, but with the environmental conditions of the target site, including the effect of Martian gravity.

With the above technical review, it was observed that most of the solutions related to the modular construction connection have been implemented in buildings. Therefore, the researchers of the present publication are currently developing possible alternatives by means of bolted connections.

Box 2

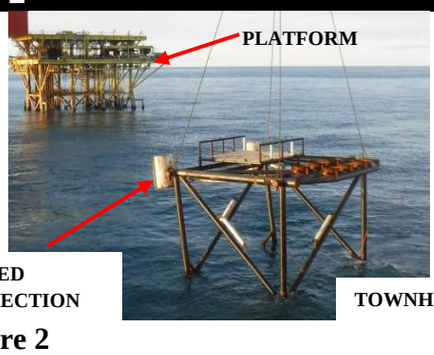

Figure 2

Attached structure, with bolted connection

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Journal of Innovative Engineering December 2024 Vol.8 No.23 12-20
Article

In order to optimise costs it is proposed to use smaller crane ships, for which it is intended to design marine jackets to be installed in segments (modules) with bolted connections, these segments have weights of less than 800 tons, allowing the installation with smaller ships, the installation of the segments by means of this type of connections will allow easy installation. The substructure installed in segments is easy to dismantle and relocate to other new oil fields, allowing its reuse. Additionally, it will be applicable in cases where oil companies in Mexico require to enable short-term wells, i.e. 5 years of production.

Methodology

This section shows the structural analysis through a structural model of the on-site conditions, considering the functionality of the proposed platform in segments.

A structure is proposed that is divided into several segments as shown in Figure 3, this structure has the following characteristics:

a) **Easy installation:** installed in segments, to use crane ships with an average assembly capacity of 800 tonnes. The connections of the segments will be bolted.
b) **Reduced installation costs:** the platform modules have lower weights, which allows installation with smaller capacity crane ships that are more economical.
c) **Reusability:** the platforms can be easily dismantled due to the bolted segment-based connection type.

Box 3

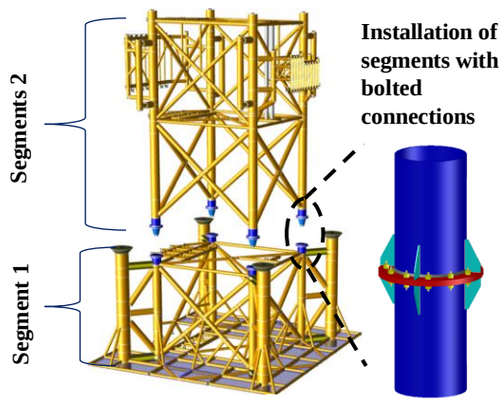

Figure 3
Marine structure type ELM, installed in segments

Loads considered in the model análisis

For the design of the ELM type tetrapod drilling service steel offshore platform, gravity loads were used as shown in Table 1 and according to Figure 4.

Box 4

Table 1
Platform loads

Item	Description (Gravitational loads)	Weight TON
1	Modelled dead load in operation	1,172.5
2	Modelled dead load in storm	1,164.4
3	Dead load in substructure	95.4
4	Unmodelled dead load in superstructure	104.8
5	Live load on superstructure	725.5
6	Load of existing equipment	153.5
7	Pipe loading	150.8
8	Non-generated dead load on south side cantilever, PIA* equipment	8.2
9	Live load on south side cantilever, PIA* equipment	63.0
10	Dead load on PIA* equipment	122.8
11	Live load on PIA* equipment	87.1
20-27	Environmental in operation@45	-
30-37	Environmental in storm @45	-

*PIA= Water injection equipment

Box 5

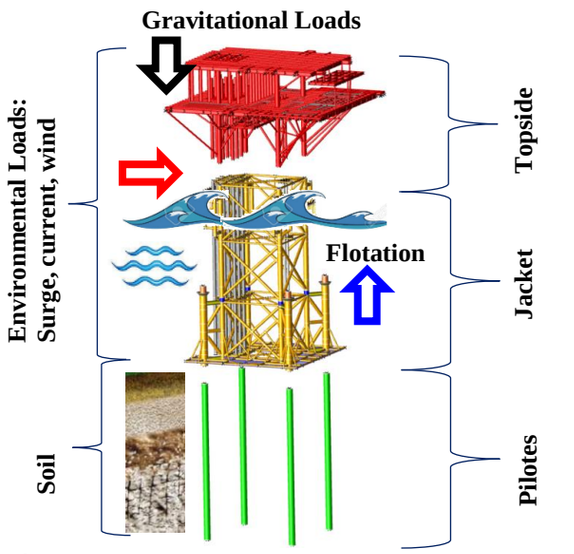

Figure 4
Scheme of applied loads according to Table 1

The operating and storm analysis conditions of the platform consider that it is subjected to environmental loads as indicated in Table 2, these parameters are wave, current and wind loads; for this analysis the values of the PEMEX technical specification P.2.0130.01-2015 (PEMEX, 2015), applied in 8 directions at every 45°, were used.

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The background of the values in Table 2, include the selection of the corresponding current function, which is generally assumed according to the current function defined by equation 1

$$\psi(x,y) = Cz + \sum_{n=1}^{N} x_n[nk(z+d)z+d]\cos(nkx) \quad [1]$$

Where, N is the order of the current function and k is the wave number. The particular solutions consist of solving equation [1] for the cases of Linear theory, which is applicable to the cases of steady-state waves, fatigue analysis, regular and uniform waves, floating and fixed structures in which inertial effects dominate; Second-order Stokes theory, recommended for the analysis of TLP structure stays; Current function theory or fifth-order Stokes theory applicable for storm surge. Additional aspects of particular solutions and applicability are given in API (2014), Fenton (1979), Atkins (1990) and Chakrabarti (2005).

Box 6

Table 2

Operating and storm environmental parameters

ENVIRONMENTAL LOADS				
Parameters	**Operation**	**Reference**	**Blizzard**	**Reference**
Maximum wave height (m):	7.10	*Figure 20	14.85	*Figure 13
Wave period (s):	8.20	*Table 17	12.18	*secc. A.1.1
Astronomical tide (m):	0.76	*Table 17	0.76	*secc. A.1.1
Storm tide (m):	0.30	*Table 17	0.74	*Figure 15
Water depth (m):	31.50		31.500	
Current velocities				
At 0% depth (cm/s):	30.0	*Table 17	125.00	*Figure 16
At 50% depth (cm/s):	25.0	*Table 17	120.00	*Figure 16
At 95% depth (cm/s):	18.0	*Table 17	116.00	*Figure 16
Viento				
Maximum wind speed at 10 m SNMM (m/s), 1 hr average: Wave Theory	14.40	*Table 17	29.15	*Table 14
Stream Function	**3**	**figure 5.3	**7**	**figure 5.3

* Values taken from Pemex technical specification P.2.0130.01:2015
**Theory based on figure 5.3 of API RP AA WSD 22ed.

The load combinations were considered in two blocks, the first for the operating conditions combined with the environmental loads applied at each 45°; the second block includes the storm conditions multiplying the gravity loads by the environmental storm loads. According to API (2014), the interaction ratio (I.R.), for axial force and moment, are reviewed through equation [2].

$$R.I. = \frac{fa}{0.6Fy} + \frac{\sqrt{fbx^2 + fby^2}}{(Fb)} \leq 1.0 \quad [2]$$

Where, fa corresponds to the axial acting stress, Fy yield stress of the steel, f_bx and f_by are the acting moments in the x & y axes, Fb the allowable moments, particular cases are given in section 6.3 of API (2014). The stress interaction ratios (R.I.) that were calculated in this analysis of the elements of the platform structure are less than the maximum permissible, complying with current regulations, with the most stressed elements being the following, see Figure 5:

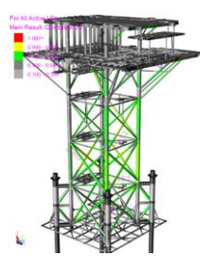
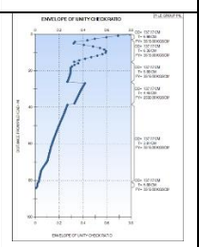
a) SUB STRUCTURE (JACKET): R.I.= 0.853, located in an A-axis Xbrace tube.

b) SUPER STRUCTURE (TOPSIDE): R.I.= 0.939 located in a girder of the first level load bearing system.

c) Revision Piles under the seabed: R.I.= 0.788, located in the pile of shaft 2B.

d) Check penetration in tubular joints: R.I.= 0.945, located in a horizontal pipe of axis B of level (-) 6.096 m.

Box 7

Stresses in Elements	Penetration of tubular joints	Pile stresses
		
R.I. máx: Jacket= 0.853 Topside= 0.929	R.I. máx: Nodo 320 = 0.945	R.I. máx: Pilote 2B = 0.788

Considering the connection the whole platform complies, due to NO overstress

Figure 5

Operation and storm analysis results, platform-wide

Structural design of the bolted connection

Table 3 lists the properties of the materials used for the bolted connection design.

ISSN: 2523-6873
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Álvarez-Bello Martínez, Rodrigo Daniel, Álvarez-Arellano, Juan Antonio and El-Hamzaoui,Youness. In-situ analysis of an intermodular connection for segmented offshore platforms. Journal of Innovative Engineering. 2024. 8-23: 12-20.
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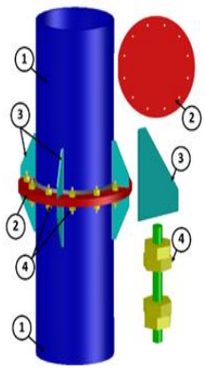
Journal of Innovative Engineering December 2024 Vol.8 No.23 12-20
Article

Box 8

Table 3

Properties and description of the bolted connection

Item	Description	parts	Scheme
1	Pipe 44 "Ø x 1.50" thick x 72" long, API 2H gr. 50, with S1, S2, S4 and S5 supplements.	2	
2	1 3/4" thick plate, 64 "Ø flange type, API 2H gr. 50, with S1, S2, S4 and S5 shims	2	
3	5/8" thick plate, stiffener type, ASTM A36	8	
4	1 1/4 "Ø X 12" long stud bolt, ASTM A193 Gr B7, ASME Specification B18.31.2 Class 2A with 4 Class 2B Hex Nuts made of AST A194 Gr 2H ASTM Specification B18.2.2 steel and 2 ASTM F436 Cadmium Plated ASTM B766 Type II Class 25 washers.	12	

According to Table 3, the elements of the bolted connection is made up of tubular elements that are part of the corresponding platform module, for the case under analysis were considered those designated as ① Pipe 44 'Ø x 1.50' thick x 72' long, API 2H gr. 50, with S1, S2, S4 and S5 supplements; ② Plate 1 3/4' thick, flange type 64 'Ø, API 2H gr. 50, with shims S1, S2, S4 and S5, as a connecting element of the connection ends of each platform module; ③ 5/8' thick plate, stiffener type, ASTM A36, whose primary function is to contribute to shear strength at the connection; ④ 1 1/4 "Ø X 12" long stud, ASTM A193 Gr B7, ASME Specification B18. 31.2 Class 2A with 4 Class 2B Hex Nuts made of ASTM A194 Gr. 2H Steel, ASME Specification B18.2.2 and 2 ASTM F436 Cadmium Plated ASTM B766 Type II Class 25 washers, whose primary function is to attach to the ② element at each end of the platform modules.

All connecting elements include material properties that comply with API (2014) recommendations for the design and construction of offshore marine platforms.

Finite element model

The analysis was performed in ANSYS software, the results of which are shown in Figure 6. The following stand out:

a) Fixed support was considered in the lower part of the model, the upper part free. The model was calibrated so that both conditions met the necessary kinematic and stability conditions.
b) The loads from table 3, corresponding to the on-site analysis, are considered.
c) The connection between the two plates (flanges) was modelled considering frictional effect between both surfaces through a Frictional element as shown in Figure 6..

Box 9

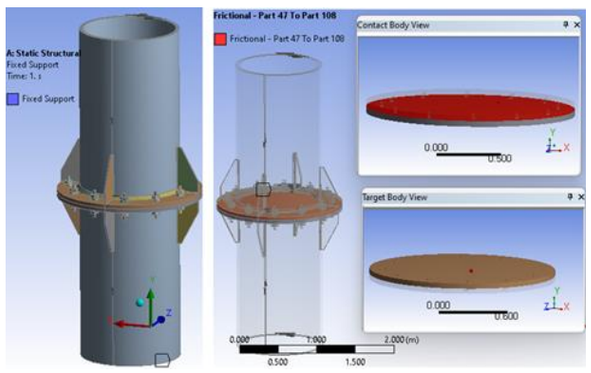


Figure 6

Structural model of the bolted connection in ANSYS

Model mesh

For the meshing of the connection, the finite element 'SOLID186' was used, being a 3-D element of 20 nodes with three degrees of freedom per node: it includes translations in the x, y and z nodal directions. The geometry of the mesh is shown in Figure 7.

Box 10

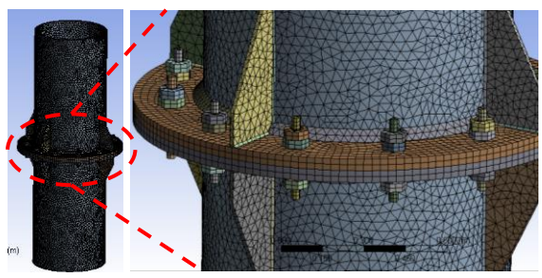


Figure 7

Meshing of the connection

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Journal of Innovative Engineering December 2024 Vol.8 No.23 12-20
Article

Figure 7, right side shows an enlarged view of the implemented mesh detail. This model includes all elements of the proposed connection consisting of the tubular element, flanges, stiffeners, studs, nuts and welding.

Discussion of results

Figure 8 and Figure 9 show the results of the analysis under the in-situ loading conditions, according to the Von Mises failure criterion for ductile materials which is defined by the equation [3].

$$\sigma_{vm} = \frac{1}{\sqrt{2}}\sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2} \quad [3]$$

Where σ_{vm} is von Mises' effort, $\sigma_3<\sigma_2<\sigma_1$, σ_1 es the maximum principal stress, □3 the minimum principal stress and □2 the average principal stress.

Box 12

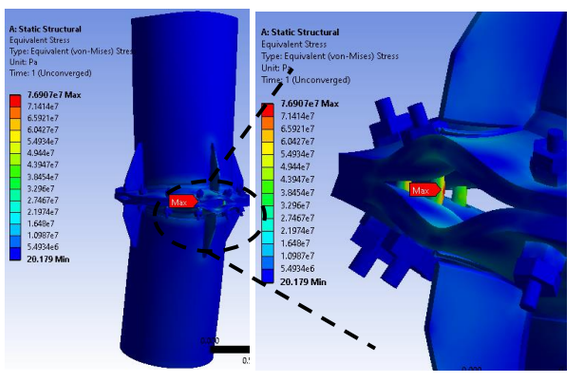

Figure 8
Von Mises forces, general isometric

According to the analysis carried out, the failure point of the connection with a maximum von Mises force value of 7.69x10e7 Pa (11.15 ksi) occurs in the studs. The ASTM A193 Gr. B7 steel stud with yield stress of 7.23x10e8 Pa (105 ksi). Comparing both results, it is observed that the acting stress is lower than the admissible stress of the material, defined as 0.90 Fy = 6.507e8 (94.5 ksi), so it is considered acceptable in terms of stresses. As well as, mechanical properties of the materials and geometry of the proposed intermodular connection for segmental offshore platforms (CIPSE).

Box 11

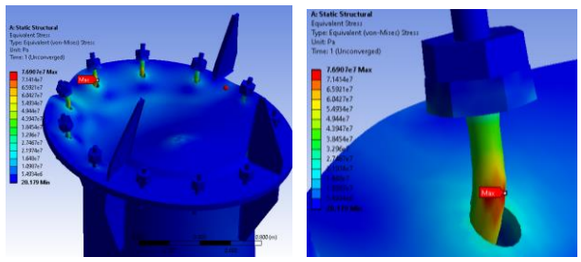

Figure 9
Von Mises' efforts, rapprochement

The previous state of stress causes the deformations in the connection shown in Figure 10, with maximum values of 0.5 mm at the end of the pipe, as well as a displacement of 0.2 mm at the flanges. Both are considered acceptable, given that they correspond in turn to acting stresses lower than those permissible.

Box 13

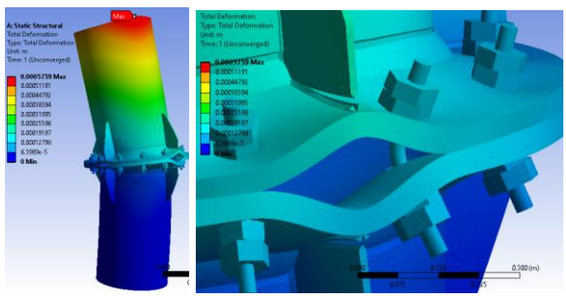

Figure 10
Deformation in connection

It is important to note that the design results mentioned above correspond to the loading conditions at the interconnection, when the modules are in place. Likewise, the mechanical properties of the materials of the elements ①, ②, ③ and ④ correspond to those recommended by the API reference (2014). The use of different characteristics requires quality tests for validation, which would make the proposed solution more expensive.

Conclusions

An ELM (light marine structure) type platform, which, is installed in modules, was analysed, highlighting the following:

1. The modules will be joined through bolted connections called intermodular connection for marine platforms in segments.

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Journal of Innovative Engineering December 2024 Vol.8 No.23 12-20
Article

2. The loading conditions represent those of the operating site.

3. The safety of the connection was reviewed by considering a finite element model which provided information in terms of the stresses under the loading condition.

4. The mechanical elements determined represent the most unfavourable loading conditions on site, which leads to stress states lower than those admissible according to the regulations applicable to the design of offshore platforms.

5. The mechanical properties of the materials considered in the investigation correspond to the recommendations of the applicable standard, which does not require additional experimental studies.

6. The implementation of this type of intermodular connection allows easy installation of platforms in segments, to use smaller crane ships, with bolted connections.

7. The proposal allows to reduce installation costs, the platform modules have lower weights, which allows the installation with smaller capacity crane ships that are more economical.

8. Because they can be dismantled, they can be reused elsewhere.

Recapitulating conclusions

1. Due to the high costs of installing offshore platforms, it is proposed to install them in segments by linking them together through an intermodular connection for offshore platforms in segments.
2. The structural design and safety review was carried out considering the loading conditions on site and the admissible stresses of the materials in accordance with current regulations.

Existing connection solutions in modular construction correspond to building structures, where the loading conditions are different, so the proposed connection represents a valuable alternative for offshore platforms.

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Declarations

Conflict of interest

The authors declare that they have no conflicts of interest. They have no known competing financial interests or personal relationships that might have appeared to influence the article reported in this paper.

Authors' contribution

Álvarez-Bello Martínez, Rodrigo Daniel: Performed the structural model of the offshore platform (Jacket, Topside and piles), gravity and environmental loads, load combinations and properties of the elements, including on-site analysis by operation and static storm, verifying regulatory compliance and interpretation of the corresponding results.

Álvarez-Arellano, Juan Antonio: Contributed in the mathematical approach for the application of loading conditions and finite element modeling of the bolted connection including its components.

El-Hamzaoui, Youness: Carried out the exhaustive review and validation of the global and local analysis, as well as the conclusions of the research results.

Availability of data and materials

The data reported in this research are available for consultation on an as-needed basis.

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Journal of Innovative Engineering December 2024 Vol.8 No.23 12-20
Article

Abbreviations

PEMEX	Petróleos Mexicanos
ELM	Marine lightweight structures
ETP	Particular technical specification
TLP	Cable-tightened floating offshore platform
API	American Pretroleum Institute
U.C.	Unity check: of Stress Interaction Relationship
R.I.	Stress interaction relationship
fa	Axial stress
F_y	Yield stress of steel
f_{bx}	Acting moments about x-axis
f_{by}	Acting moments about y-axis
F_b	Permissible moments
ASTM	American Society for Testing and Materials
ASME	American Society of Mechanical Engineer
ANSYS	Engineering Simulation Software
CIPSE	Intermodular connection for offshore platforms in segments

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Journal of Innovative Engineering December 2024 Vol.8 No.23 21-28
Article

Case study of nutritional supplement for livestock, result of the pecan nut process in the state of Chihuahua, Mexico

Estudio de caso de suplemento alimenticio para ganado, resultado del proceso de la nuez pecanera en el estado de Chihuahua, México

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Abstract

The south-central region of the State of Chihuahua is characterized by being a walnut producing area, in Cd. Delicias. There are ten companies of international stature dedicated to processing pecan nuts. Analyzing the feasibility of using the scrap that these companies discard when breaking the nut and converting it into a useful product such as concentrated livestock feed, which can be marketed, in addition to the nutritional contributions it has. This city is identified as being an important dairy basin, which is why cattle need molasses, mineral salts and some other types of nutrients, which is why this work was developed dedicated to the study of the scrap content that results at the end of the process of cracking the pecan nut in the processing companies, being an area of interest, in which the innovation of using very small parts of the walnut kernel, mixed with other waste produced by this agroindustrial process, taking advantage of this value chain, is analyzed the probability of manufacturing a feed supplement for livestock, converting what they consider waste into a marketable product. To prepare the nutritional table, different statistical studies were developed, which supported the theory and unconditional advice of the Center for Research in Food and Development A.C. Cd. Delicias, Chihuahua, attached to CONAHCYT.

Case study of nutritional supplement for livestock, result of the pecan nut process in the state of Chihuahua, Mexico		
Objectives	**Metodology**	**Contribution**
Develop livestock feed concentrate from walnut scrap	Food Research and Development Center A.C. Cd. Delicias, Chihuahua, attached to CONAHCYT	Case study to develop a nutritional table from walnut scrap, formulating a nutritional diet for livestock

Case Study, Walnut Scrap, Nutritional Analysis

Resumen

La región centro sur del Estado de Chihuahua, se caracteriza por ser una zona productora de nuez, en Cd. Delicias. Existen diez empresas, de talla internacional dedicadas a procesar nuez pecanera. Analizando la factibilidad del uso del scrap que estas empresas desechan al quebrar la nuez y convertirlo en un producto de utilidad como lo es alimento concentrado para ganado, el cual se puede comercializar, además de las aportaciones nutrimentales que posee. Esta ciudad se identifica por ser una importante cuenca lechera, por lo cual el ganado bovino necesita melaza, sales minerales y algunos otros tipos de nutrientes, es por eso que se desarrolló el presente trabajo dedicado al estudio del contenido del scrap que resulta al final del proceso de quebrado de la nuez pecanera en las empresas beneficiadoras, siendo un área de interés, en el cual la innovación de utilizar partes muy pequeñas de la almendra de nuez, mezcladas con otros residuos que arroja este proceso agroindustrial aprovechando esta cadena de valor, se analizó la probabilidad de fabricar un suplemento alimenticio para ganado, convirtiendo lo que ellos consideran deshecho en un producto comercializable. Para la elaboración de la tabla nutrimental, se desarrollaron diferentes estudios estadísticos, que fue lo que apoyo a la teoría y la asesoría incondicional del Centro de Investigación en Alimentación y Desarrollo A.C. Cd. Delicias, Chihuahua, adscrito a CONAHCYT.

Estudio de caso de suplemento alimenticio para ganado, resultado del proceso de la nuez pecanera en el estado de Chihuahua, México		
Objetivos	**Metodología**	**Contribución**
Desarrollar concentrado alimenticio para ganado del scrap de nuez	Centro de Investigación en Alimentación y Desarrollo A.C. Cd. Delicias, Chihuahua, adscrito a CONAHCYT	Estudio de caso, para desarrollar tabla nutrimental proveniente del scrap de la nuez, formulando dieta alimenticia para ganado

Estudio Caso, Scrap de Nuez, Análisis Nutrimental

Citation: Aguirre-Orozco, Mario Abelardo, Morales-Aguilar, José Socorro, Morales-Chávez, Emmanuel and Contreras-Martínez, Jesús José. Case study of nutritional supplement for livestock, result of the pecan nut process in the state of Chihuahua, Mexico. Journal of Innovative Engineering. 2024. 8-23: 21-28.

Journal of Innovative Engineering December 2024 Vol.8 No.23 21-28
Article

Introduction

Cd. Delicias, Chihuahua, Mexico, is a walnut producing region, and the walnut processing business in the state is a pioneer in the country providing fifty-four thousand tons of pecan nut, like any industrial process generates waste that companies do not take advantage of for their economic benefit, however, the product is characterised by being scrap resulting from the manufacturing process of this type of agro-industries that most of them do not know what to do with it, depositing it in different sectors of the city, reflecting as environmental pollution, without knowing that this type of process generates business opportunities, due to the nutritional properties contained in the waste that the walnut processing companies throw away.

This is where the opportunity to generate agro-industries in this area arises, as it was found that this type of waste contains 20% of different proteins per 100 grams, according to studies carried out on these products at the Centro de Investigación en Alimentación y Desarrollo A.C. in Cd. Delicias, Chihuahua, Mexico, in addition to the field research where a survey was applied to different cattle, goat and sheep producers, obtaining interesting results that reflect that this study is viable and feasible to develop a product for the livestock sector in the country, considered as a feed supplement for concentrated cattle that provides a higher nutritional value at a lower economic cost, with respect to the concentrates that already exist in the market.

The proportion of husk and powder generated is so high that it is seen as an area of opportunity for commercialisation, and its properties include the fact that it is rich in macronutrients and micronutrients. Likewise, in the south-central region of the state of Chihuahua there are two hundred and fifty-seven potential customers according to SAGARPA (2017). In Ciudad Delicias, Chihuahua within its agricultural activities, as there are some sectors that are dedicated to raising cattle, as well as sheep and goats. As a first step, the background of walnut production at international, national, state and local level was addressed in order to know the percentages of discarded residues derived from the different processes to which the pecan nut is subjected.

Subsequently, the properties of the scrap generated in the processing of these agro-industries are mentioned.

In order to identify the physical and chemical properties of this product and to distinguish which of these benefit the nutritional development of livestock to be used in the production of animal feed supplements.

In addition, the methodology followed to obtain the data on the properties contained in the scrap, acquired at the Centro de Investigación en Alimentación y Desarrollo A.C. (CIAD) in Cd. Delicias Chihuahua, attached to CONAHCYT, will be explained.

Since in this work we obtained true results from reliable sources, these data were also verified with scientific technical instruments, to later compare the properties of these residues against those of other supplements made with some vegetables, as well as feed supplements that come from residues other than walnut shells that help different types of livestock for their nutrition and fattening, such as the supplement based on cotton and corn husks.

The feasibility of the feed supplement was also analysed by means of the business plan, as it provides the strategies to achieve the research objective and an estimate of the amount of investment required to finance the project, as well as the economic analysis, the market plan, the operations plan and finally the financial plan, which is probably the most important part of the business plan as it analyses the economic and financial feasibility of the project in the short and long term.

Justification

In this project, the reasons why it is important to develop this type of research are presented. In this particular case, the problem refers to the fact that there is a large amount of waste from walnut shells discarded by the industries that process them, and the nutrients they contain are not used, which can be used as balanced feed for different types of livestock.

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Journal of Innovative Engineering December 2024 Vol.8 No.23 21-28
Article

General objective

To reuse the scrap from pecan nut processing companies in the south-central region of the State of Chihuahua, Mexico, and convert it into a feed supplement for livestock, through the physical-chemical analysis of particles in the Plant Physiology and Nutrition laboratory of the Centro de Investigación en Alimentación y Desarrollo A.C. (CIAD) in Cd. Different process engineering techniques were found to take advantage of the residue from the manufacturing process of the agro-industries that transform pecan nuts.

Materials and methods

In order to address the issue of nut transformation, it is necessary to know the process in which each of the relevant activities are carried out. For this purpose, figure 1 shows the process flow diagram of the pecan nut in an agro-industry in the central-southern region of the State of Chihuahua, Mexico**.**

Process flow diagram

Box 1

Walnut processing	Agro-industrial Company	Current method	16-mar-17
Realised by MLDM	Aprobó: MAAO		
Activity	Activity No.	Symbol	Time
Walnut reception	1		T.I
Sampling	2		5 min
Warehouse	3		T.I
Walnut sorted by lot size	4		15 min
Basket filling	5		T.I
Walnut washing already in basket	6		10 min
Nut drying	7		T.I
Passage through vibrators	8		5 min
Shelling process	9		10 min
The nut that is not extracted in its entirety is passed through a water-based machine to rescue the small nut.	10		20 min
Fire and air drying process	11		30 min
It empties into the boats	12		5 min
Washes again	13		20 min
Passes through the electronic eye	14		15 min
The canisters pass to the inspection table	15		15 min
The canisters move to the packing area	16		5 min
Stored in the cold room	17		T.I

Figure 1

Process Flow diagram for obtaining scrap derived from walnut

Box 2

Abstrac	
Activity	Totals
	110 min
	20 min
	25 min
	T.I
Total time (min)	135
Distance (mts)	30 mts
Total activities	17

Figure 2

Summary of the flowchart

The flow chart is relevant in this study, as it explicitly visualises the level of detail during the process in which scrap is generated. Once it has been identified in the process how the waste is generated and above all the amount of waste, it can be seen that it is viable for the production of the cattle feed supplement. For the physical-chemical analysis of the components, three samples were requested from one of the companies in the region, the first consisting of the three components, almond, walnut and cork, the second consisting of walnut shells mixed with cork and the third consisting of walnut shells, which were then taken to the Centro de Investigación en Alimentación y Desarrollo A.C., in Delicias City, Chihuahua, where the following tests were carried out.

Acid digestion procedure

To identify the properties of the waste derived from pecan nut processing, the Centro de Investigación en Alimentación y Desarrollo A.C. in Cd. Delicias was attended, where two replicates of approximately one gram of each type of scrap were taken, using a high resolution food scale, six aluminium beakers, among other laboratory utensils to classify the samples, as described in figure 8, obtaining the properties identified as shown in table 1.

Box 3

Table 1

Sample weights for acid digestion

(Sample consisting of almond, walnut and cork)		(Sample composed of walnut shells mixed with cork.		(Sample composed of walnut shells)	
T1		**T2**		**T3**	
R1 1.0025g	R2 1.0060 g	R1 1.0076 g	R2 1.0010 g	R1 1.0083 g	R2 1.0043 g

Aguirre-Orozco, Mario Abelardo, Morales-Aguilar, José Socorro, Morales-Chávez, Emmanuel and Contreras-Martínez, Jesús José. Case study of nutritional supplement for livestock, result of the pecan nut process in the state of Chihuahua, Mexico. Journal of Innovative Engineering. 2024. 8-23: 21-28
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Journal of Innovative Engineering December 2024 Vol.8 No.23 21-28
Article

Box 4

Figure 3
High resolution weighing scale
Source: CIAD 2017

Once the samples were weighed and identified in the respective beakers, they were subjected to the acid digestion process, which consists of pouring a triacid solution, composed of 25 ml. of sulphuric acid, 100 ml. of hydrochloric acid and one litre of nitric acid, to the six samples, adding three glass beads to each sample (to avoid the solution jumping with the combustion that is generated).

In order to heat the samples for about one and a half hours. As shown in figure 4. This is so that the acid acts and disintegrates the organic matter, leaving only the minerals in the sample, which are the ones of interest.

Box 5

Figure 4
Acid Digestion
Source: CIAD 2017

Box 6

Figure 5
Filtration process
Source: CIAD 2017

After approximately one and a half hours, when the acid digestion to which the samples were subjected had been completed, they were filtered using laboratory utensils (figure 5), and then the filtered samples were diluted with tridistilled water and subjected to atomic absorption spectroscopy, and the analysis began to determine the quantities of the nine elements that the apparatus is capable of identifying.

Procedure for obtaining the nine elements using atomic absorption spectroscopy

1. The samples are identified in the software as T1, T2 and T3 with their respective replicates (R1 and R2).

2. The flame of the Thermo Scientific equipment was stabilised by letting it work with a substance identified as a blank (triacid substance), which is absorbed by a capillary, fulfilling the function of purifying the equipment for approximately five minutes.

3. The Cu (copper) of the three samples was read, placing the capillary in each replicate of the samples, as well as in the washing substance between each change of sample, as indicated by the software, and finally the data of each replicate was captured.

4. Directly from the samples T1 (R1 and R2), T2 (R1 and R2) and T3 (R1 and R2) as with C (copper) the elements Na (sodium), Fe (iron), Zn (zinc), Ni (nickel) and Mn (manganese) will be obtained.

5. To calculate the elements Ca (calcium), Mg (magnesium) and k (potassium) the samples were calibrated. Tridistilled water was placed halfway into a flask. In addition, 50 micro litres of the samples T1 (R1 and R2), T2 (R1 and R2) and T3 (R1 and R2) were added. Subsequently, tridistilled water is carefully added up to the mark indicated on the flask. Finally, shake with both hands.

6. Once the samples have been shaken, they are poured into the centrifuge tubes previously identified and the analysis is carried out in the same way as the procedure followed in step three to obtain the reading of the elements (Ca, Mg and K).

ISSN: 2523-6873
RENIECYT-CONAHCYT: 1702902

Journal of Innovative Engineering December 2024 Vol.8 No.23 21-28
Article

Box 7

Figure 6
Atomic absorption equipment
Source: CIAD 2017

Box 8

Table 2
Results of atomic absorption by element

Results from the CIAD Laboratory:

Element	Sample	Replica	Concentration	0	Result	Average %
Ca	TI	R1	0.2133	0.5	0.10665	0.11085
		R2	0.2301	0.5	0.11505	
	T2	R1	0.2141	0.5	0.10705	0.119075
		R2	0.2622	0.5	0.1311	
	T3	R1	0.194	0.5	0.097	0.09895
		R2	0.2018	0.5	0.1009	
Cu	TI	R1	0.0746	50	3.73	3.6525
		R2	0.0715	50	3.575	
	T2	R1	0.0603	50	3.015	3.475
		R2	0.0787	50	3.935	
	T3	R1	0.1886	50	9.43	10.1975
		R2	0.2193	50	10.965	
Fe	TI	R1	1.0158	0.5	0.5079	0.57595
		R2	1.288	0.5	0.644	
	T2	R1	0.6364	0.5	0.3182	0.356925
		R2	0.7913	0.5	0.39565	
	T3	R1	0.6114	0.5	0.3057	0.341475
		R2	0.7545	0.5	0.37725	
K	TI	R1	0.3806	0.5	0.1903	0.224225
		R2	0.5163	0.5	0.25815	
	T2	R1	0.5432	0.5	0.2716	0.3033
		R2	0.67	0.5	0.335	
	T3	R1	0.5891	0.5	0.29455	0.346025
		R2	0.795	0.5	0.3975	
Mg	TI	R1	0.1019	0.5	0.05095	0.05445
		R2	0.1159	0.5	0.05795	
	T2	R1	0.1048	0.5	0.0524	0.0572
		R2	0.124	0.5	0.062	
	T3	R1	0.174	0.5	0.087	0.0951
		R2	0.2064	0.5	0.1032	
Mn	TI	R1	0.5634	50	28.17	26.1175
		R2	0.4813	50	24.065	
	T2	R1	0.5421	50	27.105	28.6375
		R2	0.6034	50	30.17	
	T3	R1	0.5666	50	28.33	31.02
		R2	0.6742	50	33.71	
Mg	TI	R1	0.0544	50	2.72	2.93
		R2	0.0628	50	3.14	
	T2	R1	0.0782	50	3.91	3.355
		R2	0.056	50	2.8	
	T3	R1	0.0868	50	4.34	4.4075
		R2	0.0895	50	4.475	
Mg	TI	R1	0.2481	50	12.405	13.055
		R2	0.2741	50	13.705	
	T2	R1	0.225	50	11.25	11.6025
		R2	0.2391	50	11.955	
	T3	R1	0.6043	50	30.215	33.8425
		R2	0.7494	50	37.47	
Mg	TI	R1	5.83848715	0	0.029192	0.02952106
		R2	5.96993542	0	0.02985	
	T2	R1	5.94301462	0	0.029715	0.16715571
		R2	60.9192705	0	0.304596	
	T3	R1	6.40554047	0	0.032028	0.032433
		R2	6.5677948	0	0.032839	34

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Flash 2000 equipment procedure to obtain the elements (CHONS and PROTEIN)

The samples T1 (R1 and R2), T2 (R1 and R2), T3 (R1 and R2) obtained again, have to be thought in a high resolution equipment called Metter Toledo (figure 7), for which nothing of the process should be manipulated with the hands, because in the Flash 2000, the humidity can generate variation and everything should be done by means of tweezers and other laboratory utensils. The equipment is switched on and set to zero. Between 9 and 11 milligrams of reagent is added to the container, which is weighed and the equipment is reset to zero again, after which the sample is carefully added, which should weigh more than 3,300 mg and less than 3,500 mg (recommendation). The process is done with each of the samples (T1, T2 and T3) with their respective replicates (R1 and R2). The samples were taken with the special equipment in an isolated area to avoid the variation that may be generated by direct contact with the environment. As shown in table 3.

Box 9

Table 3
Sample weights for Flash 2000

(Sample consisting of almond, walnut and cork)		(Sample composed of walnut shells mixed with cork.		(Sample composed of walnut shells)	
T1		**T2**		**T3**	
R1 3.256 mg	**R2 3.272 mg**	**R1 3.050 mg.**	**R2 3.303 mg**	**R1 3.91 2 mg**	**R2 4.61 9 mg**

Subsequently, they were introduced into the Flash 2000 equipment, for the detection of the elements (CHONS and PROTEIN). The equipment takes approximately 6 hours to detect the elements.

Box 10

Figure 7
Metter Toledo equipment
Source: CIAD 2017

Aguirre-Orozco, Mario Abelardo, Morales-Aguilar, José Socorro, Morales-Chávez, Emmanuel and Contreras-Martínez, Jesús José. Case study of nutritional supplement for livestock, result of the pecan nut process in the state of Chihuahua, Mexico. Journal of Innovative Engineering. 2024. 8-23: 21-28
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Journal of Innovative Engineering December 2024 Vol.8 No.23 21-28
Article

Results

The results of the amounts of elements (CHONS) and the amount of Protein obtained in the three types of samples (T1, T2 and T3) with their respective replicates (R1 and R2) are shown in table 4.

1. The spectrophotometer for the detection of Phosphorus (P) Procedure to obtain it: 1.

Box 11

Table 4

Flash 2000 results

Sample No.		N(%)	Carbon	Hydrogen	% Sulphur	% Protein
T1	R1	3.182	48.2396	4.1969	0	19.8918
	R2	3.228	47.3942	6.3398	0	20.1769
T2	R1	2.884	47.8531	4.1037	0	18.0251
	R2	3.014	48.042	6.3473	0	18.8414
T3	R1	2.95	47.8998	6.3247	0	18.4376
	R2	2.758	48.4065	6.2656	0	17.2389

6 cells will be used to enter the equipment (Figure 8).

Box 12

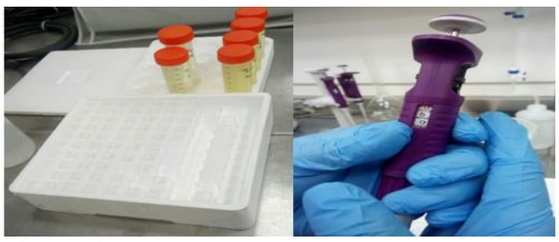

Figure 8

Celdillas and micropithet

Source: CIAD 2017

2. Using a micropipette, they will be added to each cell, as shown in figure 9. The following substances shall be added to each cell as shown in Figure 9, calibrating the equipment to the units of each substance to be added:

500 mil. sample -050 (P)
1 mil. of P reagent -100
3.5 mil. deionised wáter

Box 13

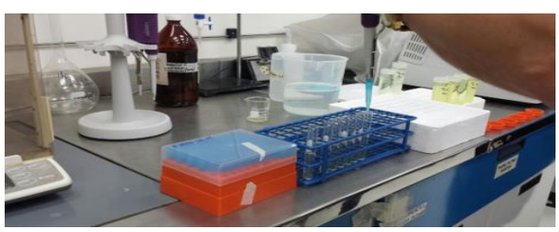

Figure 9

Cells with the substances obtained

3. Shake to mix the samples thoroughly in the cells with a shaker (Figure 10), which takes 2 seconds to homogenise the sample.

Box 14

Figure 10

Cells with the substances obtained

Source: CIAD 2017

Box 15

Table 5

Spectrophotometer results for the detection of Phosphorus

Sample No.	Replicas	P(%)
TI	R1	0.1366
	R2	0.0945
T2	R1	0.0838
	R2	0.0402
T3	R1	0.0924
	R2	0.0838

4. Leave the cells to stand for 1 hour.

After resting the samples for 1 hour, we proceed to the reading in the Thermo scientific (GENESYS 10S UV-VIS) by placing the samples on the carousel of the equipment and proceed to the analysis at a wavelength of 430 nanometres.

The results taken from (T1, T2 and T3) with their respective replicates (R1 and R2) are shown in table 5. Where the percentage of Phosphorus (P) contained in the respective samples were obtained by phosphorus spectroscopy using the Molybdate Vanadate technique.

Table 6 shows the PPM amounts and the percentage (%) of the 15 elements obtained through the tests carried out at CIAD. Such as atomic absorption, flash 2000 and spectroscopy for each type of sample. These samples will be compared after their analysis and a decision will be made as to which sample to use in the preparation of the supplement, and finally conclusions will be drawn.

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Box 16

Table 6

Overall results of the samples

Samples	Elements	Contents	Units
T1	Ca	0.11085	%
	Cu	3.6525	PPM
	Fe	57.595	PPM
	K	0.224225	%
	Mg	0.05445	%
	Mn	26.1175	PPM
	Ni	2.93	PPM
	Zn	13.055	PPM
	Na	0.029521056	%
	N	3.205	%
	P	0.11555	%
	C	47.8169	%
	H	5.26835	%
	S	0	%
	PROTEINA	20.03435	%
T2	Ca	0.119075	%
	Cu	3.475	PPM
	Fe	35.6925	PPM
	K	0.3033	%
	Mg	0.0572	%
	Mn	28.6375	PPM
	Ni	3.355	PPM
	Zn	11.6025	PPM
	Na	0.00087354	%
	N	2.949	%
	P	0.062	%
	C	47.94755	%
	H	5.2255	%
	S	0	%
	PROTEINA	18.43325	%
T3	Ca	0.09895	%
	Cu	10.1975	PPM
	Fe	34.1475	PPM
	K	0.346025	%
	Mg	0.0951	%
	Mn	31.02	PPM
	Ni	4.4075	PPM
	Zn	33.8425	PPM
	Na	0.032433338	%
	N	2.854	%
	P	0.0881	%
	C	48.15315	%
	H	6.29515	%
	S	0	%
	PROTEINA	17.83825	%

Conclusions

When analysing the quantities of each sample (T1, T2 and T3), it was observed that the sample that stands out in terms of properties is T1.

Composed of walnut, shell and cork particles. As shown in table 7. In which you can see its high protein content with 20% of each 1000 mg. Equivalent to 200g of pure protein per kilogram.

In phosphorus it has 11% of each 1000 mg. Equivalent to 110g per kilogram and calcium in quantities of 11% of each 1000 mg; giving the same equivalence as phosphorus.

Box 17

Table 7

Properties of sample T1

Samples	Elements	Contents	Units
T1	Ca	0.11085	%
	Cu	3.6525	PPM
	Fe	57.595	PPM
	K	0.224225	%
	Mg	0.05445	%
	Mn	26.1175	PPM
	Ni	2.93	PPM
	Zn	13.055	PPM
	Na	0.029521056	%
	N	3.205	%
	P	0.11555	%
	C	47.8169	%
	H	5.26835	%
	S	0	%
	PROTEINA	20.03435	%

According to the (Manual of fodder banks, 2001). It states that for cattle the nutritional requirements of a dual-purpose cow are as follows:

Box 18

Table 8

Requirements by fodder bank for livestock

Nutrition	Requirement
Protein	820 gr por día
Energy	14.0 Mcal * por día
Football	20.0 gr por día
Phosphorus	16.0 gr por día

If cattle are fed four to five kilograms of the supplement per day, it will meet the specifications set out in Table 8. Therefore, it is proven that the cattle supplement made from walnut shell residue meets the requirements and thus proves the hypotheses stated in this research.

Declarations

Conflict of interest

The authors declare that they have no conflicts of interest. They have no known competing financial interest or personal relationships that could have influenced the publication of the article reported in this research.

Authors' contribution

Aguirre-Orozco, Mario Abelardo: Main author of the article, recognised by SNI Level I CONAHCYT

Morales-Aguilar, José Socorro: Co-author

Morales-Chávez, Emmanuel: Co-author

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Contreras-Martínez, Jesús José: Co-author

Availability of data and materials

The research was carried out at the Centro de Investigación en Alimentación y Desarrollo A.C. Cd. Delicias, Chihuahua, attached to CONAHCYT, by means of the physical-chemical analysis of particles in the Plant Physiology and Nutrition laboratory. Different process engineering techniques were found to take advantage of the residue from the manufacturing process of the agro-industries that transform pecan nuts.

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Article

Practical guide for assessing the need for conservation or modernization of roads in Mexico

Guía práctica para evaluar la necesidad de conservación o modernización de carreteras en México

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Abstract

Given the accelerated deterioration of the road network in Mexico, the proposed guide presents a rigorous methodological approach that facilitates decision-making between the conservation and modernization of road segments, ensuring their functionality and safety. Developed in response to the concerning state of the National Road Network (RNC), this guide combines documentary research with field evaluations, providing a robust technical tool for engineers and technicians to make informed decisions. It is based on key indicators such as signage, pavement condition, and geometric design. To validate its application, a case study was conducted on a road section in the Municipality of Valle de Bravo, State of Mexico, demonstrating the importance of implementing modernization work when conditions require it. This guide establishes itself as an indispensable tool for the strategic management of road infrastructure, optimizing resource allocation and ensuring that Mexican roads meet the demands of transportation, with a focus on safety and efficiency.

Objectives

Provide a methodological guide that allows engineers and technicians to assess the need to conserve or modernize road sections in Mexico.

Results: The guide, validated through a case study.

Contributions: The development of a methodology that offers a comprehensive approach combining documentary analysis and field studies to accurately assess the condition of roads.

Methodology

1. Data Collection

2. Assessment of Current Conditions

3. Identification of Necessary Interventions

Methodological, Deterioration, Evaluation

Resumen

Ante el acelerado deterioro de la red vial en México, la guía propuesta presenta un enfoque metodológico riguroso que facilita la toma de decisiones entre la conservación y la modernización de tramos carreteros, garantizando su funcionalidad y seguridad. Desarrollada en respuesta al preocupante estado de la Red Nacional de Caminos (RNC), esta guía combina investigación documental con evaluaciones de campo, ofreciendo una herramienta técnica sólida para que ingenieros y técnicos tomen decisiones informadas. Se fundamenta en indicadores clave como la señalización, el estado del pavimento y el diseño geométrico. Para validar su aplicación, se llevó a cabo un estudio de caso en un tramo carretero en el Municipio de Valle de Bravo, Estado de México, demostrando la importancia de implementar trabajos de modernización cuando las condiciones lo requieren. Esta guía se consolida como una herramienta indispensable para la gestión estratégica de la infraestructura vial, optimizando la asignación de recursos y asegurando que las carreteras mexicanas respondan a las exigencias del transporte, con un enfoque en la seguridad y la eficiencia.

Objetivos

Proporcionar una guía metodológica que permita a ingenieros y técnicos evaluar la necesidad de conservar o modernizar tramos carreteros en México

Resultados: La guía, validada mediante un estudio de caso.

Contribuciones: El desarrollo de una metodología que aporta un enfoque integral que combina el análisis documental y estudios de campo para evaluar de manera precisa el estado de las carreteras.

Metodología

1.Recolección de datos

2.Valoración del estado actual

3. Identificación de la intervención necesaria

Metodología, Deterioro, Evaluación

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Journal of Innovative Engineering December 2024 Vol.8 No.23 29-36
Article

Introduction

Road infrastructure is an essential component for the economic and social development of any nation, connecting communities, facilitating trade and ensuring the mobility of people and goods (Zapata Rogel et al., 2023). However, factors such as population growth, intensive use and adverse weather conditions contribute to the progressive deterioration of this infrastructure, compromising its safety, functionality and service capacity (Zavala & Abarca, 2023). This problem is especially relevant in Latin America, where the road network lags behind in terms of maintenance and modernisation (ECLAC, 2021).

In Mexico, the National Road Network (RNC) comprises 178,217 km of paved roads, distributed between federal (28.80%), state (57.80%) and municipal/private (13.40%) roads (IMT, 2023). In addition, only 38% of the federal toll-free road network is in good condition, according to data from the Ministry of Infrastructure, Communications and Transport (SICT, 2022). The remaining 62% present conditions ranging from fair to poor, which negatively impacts the national economy, increasing transport costs, reducing productivity and limiting access to markets and services (World Bank, 2014). In addition, poor roads increase the risk of road accidents, affecting road safety (WHO, 2018).

While road maintenance is essential, population growth and new user demands require an approach that goes beyond routine activities. Comprehensive strategies are required to expand road capacity, strengthen safety, and adopt innovative technologies to ensure modern and efficient infrastructure.

Against this backdrop, a key question needs to be answered: Is it better to maintain existing roads through maintenance, or is it better to invest in their comprehensive modernisation? The answer to this question requires a thorough assessment that considers technical, economic and social factors (SHCP, 2015).

In this context, the distinction between maintenance and modernisation works on Mexico's roads becomes a critical issue to optimise investment in road infrastructure and ensure transport safety and efficiency.

While maintenance focuses on repairing existing damage to pavements, signalling and other elements, modernisation involves the construction of new roads or the improvement of existing roads to increase their capacity and safety (CAPUFE, 2024).

Several studies have addressed the problem of deterioration of road infrastructure in Latin America and Mexico (García Depestre et al., 2021; International Transport Forum, 2017; Dorado Pineda et al., 2019), agreeing on the need to implement efficient strategies for the management and maintenance of this infrastructure.

Currently, there are several methodologies, both nationally and internationally, that describe pavement assessment. Among them are: ASTM D 6433-99 or Pavement Condition Index (PCI, USA), the Guide for the Conduct of Visual Pavement Inspection (Spain), the Pavement Surface Assessment and Ranging (PASER, USA.), the Consorcio de Rehabilitación Vial (CONREVIAL, Peru), the Índice de Calificación Visual (ICV) for flexible pavements, the Pavement Condition Index (PCI) for rigid pavements, the Índice de Condición del Pavimento (ICP) and the Metodología de conservación de caminos de tierra o terraplenes en Cuba, among others.

Although there is an abundance of manuals and guides on maintenance techniques, the complexity of the evaluation and improvement of a road section requires more time and knowledge to carry out an exhaustive assessment, especially in obsolete sections that require modernisation beyond simple maintenance works. In view of the above, it is considered appropriate to develop a practical and simple tool to optimise decision-making regarding the need for maintenance or modernisation of road infrastructure.

This proposed guide aims to provide a tool to identify the specific needs and define the most appropriate alternative for road projects in Mexico, based on the current evaluation of signage, pavement and geometric design. Aimed at road engineers and technicians, the guide will facilitate informed decision making on investment in the maintenance or modernisation of a road network, based on the identification of key indicators.

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Journal of Innovative Engineering December 2024 Vol.8 No.23 29-36
Article

Methodology

The methodology proposed for the elaboration of this guide is based on an integrated approach combining desk research with field studies. This approach was chosen to comprehensively address the specific requirements of a road study, ensuring that maintenance or upgrading decisions are based on solid evidence and aligned with best practice. The rationale for this approach lies in the need for a rigorous and detailed analysis, allowing for an accurate assessment of the current state of roads and the identification of necessary interventions. For its development, an exhaustive review of the literature in scientific sources, theses and official documents issued by competent authorities was carried out. This guide proposes to follow three fundamental steps: data collection, assessment of the current state of the roads and identification of the necessary interventions. The main sections of each step are described below:

1. Data collection

This consists of obtaining all useful information that is closely related to the objective of this project (regulations, TDPA, geometry, vehicle classification, among others) and the following data should be obtained:

Documentary research. This is based on the collection, analysis and synthesis of information from written documents, such as books, articles, theses, technical reports, newspapers, websites, among others, according to the section under study.

Geometric information. This is the collection of data related to the design or physical configuration of a road, considering aspects such as shapes, dimensions and spatial characteristics. This information covers the trajectory, alignment, longitudinal profile, cross section, geometric elements, intersections and accesses.

Signalling information. This consists of collecting all information related to existing signage, whether vertical, horizontal, or safety devices.

Traffic information. Involves collecting data on vehicle flow and traffic conditions on the roads in the study area.

Structural information. This refers to the collection of data on the composition and arrangement of the elements which make up a road, from the surface to the base.

2. Assessment of the current state

This section involves assessing and assigning a value to the physical, structural and functional conditions of the road in question, in accordance with which it is proposed to evaluate and analyse the following items:

Signalling assessment. This involves examining and evaluating the quality, efficiency and adequacy of the traffic signs installed along the road. Verifying that the signs comply with the design standards and regulations of the SICT Road Signs and Safety Devices Manual.

Visual assessment of the road surface. This refers to the process of examining and assessing the physical and structural condition of a road surface. This involves checking for the presence of damage, imperfections or deterioration in the surface, such as potholes, cracks, subsidence, wear and tear, and other problems that may affect traffic safety and efficiency, taking into consideration the SICT Visual Pavement Inspection Manual.

Geometric evaluation. This consists of analysing and evaluating the spatial characteristics in accordance with the guidelines established in the SICT Geometric Road Design Manual. The geometric design characteristics are estimated according to the classification of the road, the topography of the terrain, the type of vehicle and the project speed; where they are adjusted to the needs of the users (TDPA), allowing a better spatial layout to be projected on the territory which guarantees safety, functionality, economy and environmental impact.

3. Identification of the necessary intervention:

When road indicators, such as signage, road surface and geometry, do not comply with the parameters established in the current regulations. It is necessary to identify the corrective actions to be implemented on the affected section. For this purpose, the following options should be considered and deliberated upon:

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Conservation: The main objective of maintenance is to restore roads to a state comparable to the original state or even to improve this state, in order to prolong their useful life. This intervention is necessary when the evaluation of the signing and pavement surface reveals deficiencies which do not meet the needs of the road, even if the road geometry is adequate.

Upgrading: The main objective of upgrading is to adapt the road to current and future traffic demands, improving its capacity, safety and efficiency. This type of intervention is necessary when the geometric evaluation shows unfavourable results, even though the signing and pavement surface meet the required standards.

Box 1

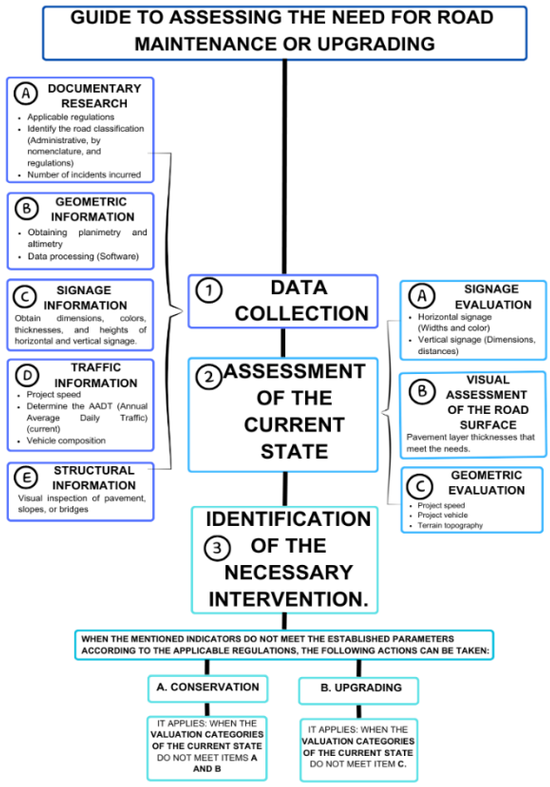

Figure 1

A practical guide to assessing the need for road maintenance or upgrading

Source: Own elaboration

Results and discusión

To assess the feasibility of the proposal contained in the guide, a case study was carried out on the road section between the towns of El Arco and Santa María Pipioltepec, in Valle de Bravo, State of Mexico.

The purpose of this analysis was to determine whether the current conditions of the section, which covers a length of 6.68 kilometres, require conservation or modernisation works, in accordance with the general objectives of the guide.

Box 2

Figure 2

Aerial view of the study section

Source: Google Earth

This section was chosen for the study due to its importance as one of the main accesses to the municipality. Currently, there has been an increase in the traffic of heavy goods vehicles, which have caused, on several occasions, accidents due to lane encroachment and significant deterioration of the pavement.

These problems highlight the need to analyse whether the maintenance works carried out by the agencies in charge have been sufficient to guarantee the safety of users or whether, on the contrary, it is necessary to undertake modernisation works to address the problems identified.

According to the first step of the proposed guide, which consists of ***DATA COLLECTION***, the following was found:

Documentary information:

- The governing regulations are the official Mexican standards.
- This road belongs to a free State network and its route is EM-001.
- According to traffic data published by the SICT in 2022, approximately 0.3% of the TDPA corresponds to vehicles type T3S3.
- No precise information on road accidents is provided on official websites; however, several notes published in newspapers refer to these incidents.

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Article

Geometric information:

Topographic survey was carried out, the collected data was transferred to a computer. Using Topcon Link software, the data was exported to CivilCAD and Civil 3D. This process allowed us to graphically visualise the real geometric conditions of the section in question, see figure 3.

Box 3

Figure 3
Carrying out of the topographic survey
Source: Own elaboration

Signalling information:

- A survey of existing vertical and horizontal signs was carried out according to their location, condition, size and colour.

Traffic information:

- The operating speed for the study section is 60 km/h, obtained from the ADDENDUM to the book Road Data 2022 by the SICT.
- The TDPA for the year 2024 is 7,437 vehicles (see Figure 4).

According to the SICT road data, Figure 5 shows the composition of vehicles.

Box 4

Figure 4
Gauge crews.
Source: Own elaboration

Box 5

Información General | Gráficas | TDPA Histórico

Ruta	EM-001
Punto Generador	Salitre
Km	66.05
Tipo	1
SC	0
TDPA2022	6485
M	8
A	88.2
B	0.5
C2	2.7
C3	0.2
T3S2	0.1
T3S3	0.3
T3S2R4	0
Otros	0

Figure 5
Vehicle classification and TDPA circulating on the study section
Source: SICT road data

Structural information:

In this section, a visual inspection was carried out at various points along the section in order to find out how the road is formed, as well as its current state. It was found that it is made up of a flexible pavement (asphalt), and it was also detected that in certain areas of the route there are a large number of potholes across the width of the road (see Figure 6), which shows that the maintenance work that has been carried out has been insufficient.

In relation to the inspection of existing slopes or bridges on the road section, it was noted that no bridges were detected on this section, and there are no slopes that have been formed by the construction of this road, which rules out the existence of landslides on the section.

Once the data collection was concluded, we proceeded to carry out the ***ASSESSMENT OF THE CURRENT STATE OF THE ROAD***, in this process the following was determined:

Evaluation of Signalling:

In this section the compliance of road signage was assessed according to the Manual of Road Signage and Safety Devices published by the SICT, having as relevant data that: Regarding the Vertical Signalling that exists in the section, taking into consideration what is established in the Manual, the following was determined.

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Box 6

Table 1

Assessment of compliance with existing vertical signage

Type of signalling	Guideline	
	Complies	Non-compliant
Restrictive signs (SR)		X
Precautionary signs (SP)		X
Information signs (SI)	X	
Safety devices (OD)		X

Source: Own elaboration

- The existing Horizontal Signage was also examined considering the guidelines established in chapter III.2. MARKS of the aforementioned manual, obtaining the following results:

Box 7

Table 2

Assessment of compliance with existing horizontal signage

Type of signalling	Guideline	
	Complies	Non-compliant
Single continuous line (M-1.1)	X	
Stripe on the right bank, continued (M-3.1).	X	
Reflective and delimiting buttons on the pavement (DH-1).		X

Source: Own elaboration

Pavement Surface Assessment:

In the analysis of this item, it is important to emphasise that when the study began, the road showed significant deterioration in the road surface along the entire stretch, with large potholes that directly affected the flow of vehicles. However, during the development of the project, maintenance works were carried out in which the condition of the asphalt layer was completely restored.

With the above mentioned, it was determined that this item is fully complied with.

Geometric evaluation

In accordance with the guidelines established in the aforementioned manual, the geometric design characteristics established in this Guide were analysed; The following describes and defines the calculation of each of the characteristics that make up the section under study:

- Regarding the Project Speed, according to the road data published by the SICT, this road belongs to a free State network and its route is EM-001, so it establishes an average speed of 60 km/hr, according to the gauging carried out, it complies with the project speed.

- In relation to the Project Vehicle, according to traffic data published by the SICT in 2022, approximately 0.3% of the TDPA corresponds to type T3S3 vehicles on the section of road under study, so as it is a type C road in accordance with the regulations, this item is complied with.

- Topography of the terrain: the objective of this activity was to obtain the existing geometric conditions of the study section, and the following table shows the points which were evaluated in this area.

Box 8

Table 3

Valorization of the geometrical characteristics of the road

Concept	Guideline	
	Complies	Non-compliant
Maximum degree of curvature		X
Governor's slope	X	
Maximum slope	X	
Roadway width		X
Crown width		X
Width of shoulders		X
Pumping	X	
Maximum over-elevation		X

As can be seen in the table, the Topography of the Terrain item does not comply in its entirety. Identifying that only 20% of the geometry of the section under study complies with the guidelines established by the regulations, otherwise 80% does not comply since the radii of curvature and other items are insufficient.

Box 9

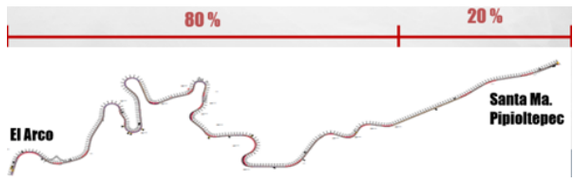

Figure 6

Identification of the road section according to its compliance

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Taking into consideration the data collection and the assessment of the current state of the road section under study, we proceeded to carry out the ***IDENTIFICATION OF THE NEEDED INTERVENTION*** in the study area, in which the following was obtained:

- The signalling does not comply
- The pavement complies
- The geometric design does not comply

Based on the above, and taking into consideration the criteria proposed in this Guide, which establishes that when the geometric evaluation yields unfavourable results, even when the signage and pavement surface meet the required standards, the road section must be upgraded, taking into account the current conditions of the section, in order to guarantee safe traffic for users.

On the basis of the above information, a space is opened up to reflect on the challenges facing road infrastructure in Mexico, specifically in the context of road maintenance and modernisation.

The complexity of determining the most appropriate intervention on a stretch of road in the need to balance the technical, economic and social aspects that influence decision-making. The detailed evaluation of the current state of roads, as presented in this article, highlights the importance of having clear methodological tools to guide engineers and technicians in the choice between preserving or upgrading a road. This discussion is crucial to optimise infrastructure investment, improve road safety and ensure transport efficiency in the country.

Conclusions

The implementation of the proposed guide has proven to be effective in identifying the necessary interventions to ensure road safety and functionality.

The rigorous data collection and detailed assessment of the current state of road sections allows for informed decisions based on solid evidence. In the specific case analysed, it was concluded that upgrading is essential due to the geometric deficiencies identified, which cannot be solved by maintenance alone.

The ‘Practical guide for assessing the need for road maintenance or modernisation in Mexico’ is established as a fundamental tool for decision-making in road infrastructure management, comprehensively addressing the challenges inherent to road maintenance and modernisation.

By integrating detailed assessment of signalling, road surface and geometric design, the guide provides a solid basis for identifying the most appropriate interventions, whether through maintenance work that extends the useful life of existing infrastructure or through modernisation projects that adapt roads to increasing traffic demands. This differentiation is crucial in the current context of Mexico, where a large part of the road network shows signs of deterioration that impact both user safety and transport efficiency.

The application of this guide will allow optimising the allocation of resources, prioritising those interventions that offer a higher return in terms of safety and functionality. In addition, the guide promotes uniformity in the evaluation of road sections at the national level, which is essential to ensure that conservation or modernization decisions are made on the basis of consistent technical criteria.

Ultimately, the implementation of this guide will contribute significantly to the improvement of the country's road infrastructure, supporting economic and social development by ensuring that Mexican roads are safe, functional and capable of meeting the needs of modern and efficient transport.

Declarations

Conflict of interest

The authors declare no conflict of interest. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

Author contribution

Gómez-Arizmendi, Gabriela: Participated in the formulation of the methodology and experimental design, carried out analyses and interpretations of the data obtained, and supervised the verification of the results to ensure the accuracy of the study.

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Rodríguez-González, José Miguel: Provided expertise in the development of the project including information management, verification and relevance, ensuring the quality of the data used throughout the process.

Bautista-Montes, Luis Pablo: Undergraduate student who contributed to the collection of data both in the field and from documentary sources, processing and organising the information needed for the project.

Availability of data and materials

The data generated are under the custody of the Tecnológico Nacional de México/TES Valle de Bravo and can be requested by contacting the corresponding author via e-mail.

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Abbreviations

ASTM	American Society for Testing and Materials
RNC	Red Nacional de Caminos
SICT	Secretaría de Infraestructura, Comunicaciones y Transportes (de México)
TDPA	Tráfico Diario Promedio Anual

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[a] Affiliation institution, Researcher ID, ORC ID, SNI-CONAHCYT ID or CVU PNPC [No.10 TNRoman]
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Introduction

Text in TNRoman No.12, single space.

General explanation of the subject and explain why it is important.

What is your added value with respect to other techniques?

Clearly focus each of its features.

Clearly explain the problem to be solved and the central hypothesis.

Explanation of sections Article.

Development of headings and subheadings of the article with subsequent numbers

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Products in development No.12 TNRoman, single spaced.

Including figures and tables-Editable

In the article content any table and figure should be editable formats that can change size, type and number of letter, for the purposes of edition, these must be high quality, not pixelated and should be noticeable even reducing image scale.

[Indicating the title at the bottom with No.10 and Times New Roman Bold]

Box

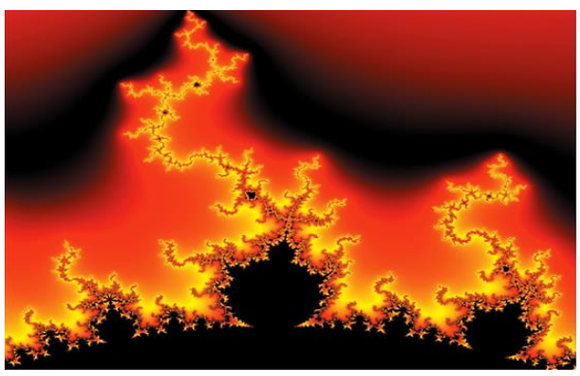

Figure 1

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Box

Table 1

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The maximum number of Boxes is 10 items

For the use of equations, noted as follows:

$$Y_{ij} = \alpha + \sum_{h=1}^{r} \beta_h X_{hij} + u_j + e_{ij} \qquad [1]$$

Must be editable and number aligned on the right side.

Methodology

Develop give the meaning of the variables in linear writing and important is the comparison of the used criteria.

Results

The results shall be by section of the article.

Conclusions

Clearly explain the results and possibilities of improvement.

Annexes

Tables and adequate sources.

The international standard is 7 pages minimum and 14 pages maximum.

Declarations

Conflict of interest

The authors declare no interest conflict. They have no known competing financial interests or personal relationships that could have appeared to influence the article reported in this article.

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Author contribution

Specify the contribution of each researcher in each of the points developed in this research.

Prot-
Benoit-Pauleter, Gerard: Contributed to the project idea, research method and technique.

Availability of data and materials

Indicate the availability of the data obtained in this research.

Funding

Indicate if the research received some financing.

Acknowledgements

Indicate if they were financed by any institution, University or company.

Abbreviations

List abbreviations in alphabetical order.

Prot-

ANN	Artificial Neural Network

References

Use APA system. Should not be numbered, nor with bullets, however if necessary numbering will be because reference or mention is made somewhere in the Article.

Use the Roman alphabet, all references you have used should be in Roman alphabet, even if you have cited an article, book in any of the official languages of the United Nations [English, French, German, Chinese, Russian, Portuguese, Italian, Spanish, Arabic], you should write the reference in Roman alphabet and not in any of the official languages.

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