ISSN 2523-2428

Journal Civil Engineering

Volume 7, Issue 18 — July — December — 2023

ECORFAN®

Journal Civil Engineering, Volume 7, Issue 18, December 2023, is a journal published biannually by ECORFAN-Peru. La Raza Av. 1047 No.-Santa Ana, Cusco Peru. Postcode: 11500. WEB: www.ecorfan.org/republicofperu, revista@ecorfan.org. Editor in Chief: JALIRI-CASTELLON, María Carla Konradis. PhD. ISSN: 2523-2428. Responsible for the last update of this issue of the ECORFAN Informatics Unit. ESCAMILLA-BOUCHÁN Imelda, LUNA-SOTO, Vladimir, updated December 31, 2023.

Journal Civil Engineering

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The works must be unpublished and refer to topics of Bridge construction, development of environmental engineering, management in housing construction, hydraulic infrastructure, soil mechanics, sanitary engineering, road infrastructure and other topics related to Engineering and Technology.

Presentation of Content

As first article we present, *Space and studio in the multi-family dwelling in the municipality of Guadalajara, Jalisco, Mexico*, by GALINDO-GONZÁLEZ, Leticia, SALAS-TAFOYA, José Manuel, VALENZUELA-GONZÁLEZ, Elizabeth and PORRAS-ZÁRATE, Iván, seconded to the Universidad de Guadalajara, as next article we present, *Economic valuation of the proper management of municipal solid waste in an educational space*, by MORENO-MARTÍNEZ, Viridiana, PALACIOS-HERNÁNDEZ, Otoniel, MORENO-MARTÍNEZ, Jatziri Yunuén and GALVÁN-CHÁVEZ Arturo, seconded to the Universidad de Guanajuato, as next article we present, *Design and construction of modular panel prototype replacing unicel with the reuse of cardboard*, by TREJO-TORRES, Zaira Betzabeth, RODRÍGUEZ-URIBE, Juan Carlos and BENITEZ-ALONSO, Margarita, with secondment at the Tecnológico Nacional de México - Instituto Tecnológico Superior de Huichapan, finally, we present, *Hydraulic concrete design with addition of natural ocoxal fiber (pine needle)*, by CASTELÁN-URQUIZA, Demetrio, seconded to the Tecnológico Nacional de México - TES de Valle de Bravo.

Content

Article

Journal Civil Engineering

December 2023, Vol.7 No.18 1-10

Space and studio in the multi-family dwelling in the municipality of Guadalajara, Jalisco, Mexico

Espacio y estudio en la vivienda multifamiliar del municipio de Guadalajara, Jalisco, México

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DOI: 10.35429/JCE.2023.18.7.1.10 Received July 10, 2023; Accepted December 30, 2023

Abstract

This work contains the results of the research about the relationship that exists between the built space of the homes of the multifamily units located in the municipality of Guadalajara and the academic learning activity. The common thread is the analysis of the relationship between spaces and requirements for the student to carry out learning activities at home. To achieve the purpose, the spaces and their dimensions that the homes of the multi-family units in the municipality of Guadalajara have and the requirements for the study at home were analyzed. The result was that these homes do not provide the possibility for the student to carry out their academic activities, since they do not have spaces for this activity and because the measurements of the homes and their spaces are small, which can only be used for basic activities and fundamental aspects of family members.

Multifamily units, Study space, Home learning

Resumen

El presente trabajo contiene los resultados de la investigación acerca de la relación que existe entre el espacio construido de las viviendas de las unidades multifamiliares ubicadas en el municipio de Guadalajara y la actividad de aprendizaje académico. El hilo conductor es el análisis de la relación entre espacios y requerimientos para que el estudiante realice las actividades de aprendizaje en casa. Para lograr el propósito se analizaron los espacios y sus dimensiones que cuentan las viviendas de las unidades multifamiliares del municipio de Guadalajara y los requerimientos para el estudio en casa. El resultado fue que estas viviendas no brindan la posibilidad de que el estudiante pueda realizar sus actividades académicas, pues no cuentan con espacios para esta actividad y por que las medidas de las viviendas y sus espacios son reducidos, los cuales solamente pueden utilizarse para actividades básicas y fundamentales de los miembros de la familia.

Unidades multifamiliares, Espacio para el estudio, Aprendizaje en casa

Citation: GALINDO-GONZÁLEZ, Leticia, SALAS-TAFOYA, José Manuel, VALENZUELA-GONZÁLEZ, Elizabeth and PORRAS-ZÁRATE, Iván. Space and studio in the multi-family dwelling in the municipality of Guadalajara, Jalisco, Mexico. Journal Civil Engineering. 2023. 7-18:1-10.

† Researcher contributing as first author.

Introduction

The Guadalajara Metropolitan Area (AMG) made up of the municipalities of "San Pedro Tlaquepaque, Tonalá, Zapopan, Tlajomulco de Zúñiga, El Salto, Juanacatlán, Ixtlahuacán de los Membrillos, Acatlán de Juárez, Zapotlanejo and the aforementioned Guadalajara" (Government of the State of Jalisco, n/d), has experienced significant urban growth in recent decades. As Jiménez (2014) points out, this urban concentration, typical of developing countries, has had in recent decades a chaotic urban development, with negative effects on the quality of life of its inhabitants. This urban growth is characterized by: i, the increase in housing developments, some in so-called multifamily units, others in vertical towers; ii, the growth has been disorderly, sometimes expansive, sometimes concentrated. The multi-family units analyzed in this paper are located in the metropolitan area, in the municipalities of San Pedro Tlaquepaque, Tonalá, Zapopan, Tlajomulco de Zúñiga and Guadalajara.

In this context, a worrisome phenomenon emerges that undermines social sustainability and the quality of life of its inhabitants. On the one hand, the aforementioned municipalities have experienced significant population growth, which has led to an increase in the number of inhabitants in the educational stage at all levels; on the other hand, the multi-family units are made up of apartments of minimal dimensions, whose physical characteristics and distribution do not favor the realization of educational learning activities at home. In addition to this situation, the needs that emerged through the COVID-19 pandemic, which generated the need for blended learning, both face-to-face and virtual, however, due to the aforementioned conditions, learning at home is not pertinent.

Given this reality, the following question arises: Do the spaces of the houses located in multifamily units in the municipality of Guadalajara allow learning at home? To answer this question, the objective of the research was "To establish the relevance of housing located in multifamily units in the municipality of Guadalajara for learning at home, through the analysis of the relationship between space and study". In order to reach this objective, a mixed type of research was carried out, from the quantitative and qualitative approaches.

Space and learning

Regarding the place for academic learning, according to Psicoadapta (2014), we find children who do not have a physical place to sit at a desk and start their homework. Many share a desk with their siblings or it is located in a passing place, or even in a large number of cases they do their homework at the living room or kitchen table. Many parents prefer to have their children close by while they do their household chores, such as preparing dinner or cleaning up the living room, which may be the most comfortable, but not the best way to study.

According to Universia (2018), several investigations have found that when a student has low achievement it is not exclusively due to the way he studies, nor to the techniques he uses to learn, but there is a close relationship with the space from which he studies; in this sense ,it has been determined that the physical space does impact directly on learning, consequently, on academic performance.

Regarding physical space, Vargas (2021) conducted an investigation in a universe of 277 university students in Cusco, Peru, taking into consideration the mandatory isolation decreed by the government and the virtual sessions proposed by the universities, through the operationalization of the categories: characteristics of spaces, functionality of spaces and housing environment. The result obtained was that the houses were not significantly and directly related to the spatial characteristics that a house should have for relevant learning.

In the same sense of physical space, Catalini et. al. (2022), in their research on studying virtually and the experiences narrated by Pedagogy students of the School of Psychology of the National University of San Luis, Argentina, found that one of the main obstacles to relevant learning at home was the impossibility of finding in domestic environments any loophole for study: the family as a producer of noise hinders study.

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As Merino (2012) points out, having an adequate study environment favors concentration to study and improve academic performance, in this sense, the place of study plays an important role in terms of the suitability of the environment, which should be comfortable and quiet and not commonly used.

Among the factors that directly affect learning is the change of place, such as the kitchen, the living room, the bed, etc., since these produce different stimuli derived from the activity to which it corresponds, in addition, by the furniture that are there or by the movement of people, or something as simple, by the different objects that are in those spaces; in short, this can contribute to the student's loss of concentration. Therefore, frequently changing the place of study due to the striking, the novelty, the unknown, the opportunity or the possibility, represents a strong stimulus, which leads the student to lose concentration. Another factor related to learning is the use of spaces for different activities such as: surfing the Internet, chatting, reading magazines, i.e., these types of activities are not ideal for concentration, therefore, they are not recommended.

From environmental psychology, Burrola (2020), considers that the study space needs certain characteristics that facilitate concentration, stimulation, encouragement and orientation in students and that environmental factors such as noise, stress, temperature and density of the interior of the house play a very important role in the proper development of a school activity. In the same sense, Torres and Rodriguez (2006), consider that the study space should favor the concentration process and avoid noises such as television, people or other types of distractions generated in the house, being ideal to study in the same space always, which should be characterized by being tidy, with a lighting that prevents the eye from being forced, as well as an adequate temperature for the organism.

In this sense, an ideal place for the student to learn is to have an express space for it, which enables the concentration process, for example, a space surrounded by nature, a space with a direct view to a natural environment, a space with enough natural light.

And, according to a study conducted by British researchers, it was shown that environments close to nature can improve creativity and productivity when studying. It should not be ruled out that the ideal place could be the student's own room, as long as it has the necessary characteristics mentioned or a space exclusively for that purpose.

Continuing with the learning environment, Aula Fácil (s/f) points out that one should avoid going to a classmate's house to study, since although it is a pleasant environment, what is really studied is little, since the time is lost in other activities caused by the proximity and coexistence, so the student will have to dedicate extra hours later on to make up for lost time. Likewise, it is not convenient to study in the public library since distraction factors are very common, this is due to the fact that going to the library is fun since you can meet with friends and chat with them.

Regarding the place for learning, García (2019) mentions that a study place should be tidy, always clean, with adequate lighting, preferably with natural light, in addition, it should have good ventilation and comfortable furniture, for example, the chair should avoid incorrect postures that lead the student to a subsequent back problem. In the same context, according to Martín (2021), the study place should always be the same, since human beings are creatures of habit and having a specific place will help to improve the ability to concentrate and develop good habits.

In this same sense, states Vergara (2021), the study place should always be the same, because if spaces such as the living room and the bedroom are mixed, messages are sent to each other, which will make it more difficult to concentrate and study, and also, it should be away from all noise for better concentration, and not have distractions such as windows in front of the desk or the television, since in the end the student does not study well, nor watch television well, in this way the student is self-deceived because as he has been a long time with the books, he considers that he has worked hard, but the only thing that has happened is that he has wasted time.

ISSN: 2523-2428

Therefore, it is recommended that the place where the student studies should be a place where there is tranquility, no noise, nothing to distract him and preferably with the door closed, this series of habits favor the student's role.

In reference to the lighting of the study space, according to Psicoadapta (2014), an adequate light source is an important factor, since it prevents fatigue caused by the effort made with the eyes. In the same context, Vergara (2021), emphasizes the importance of lighting as it is necessary to take care of the eyes from inadequate light during study hours, in this case the best is natural light, but if there is none, it can be supported by a lamp that is appropriate to the student's needs.

Regarding the temperature of the study space, Educaweb (s/f) mentions that one of the requirements for study is an adequate space and that it has adequate ventilation and correct temperature, since when these two factors are adequate, the student will feel comfortable, being this a space that can be aired frequently, as well as maintain a stable temperature, where it is not too hot or too cold, usually an adequate temperature ranges from 19Cº to 22Cº; a good way to do this would be to ventilate the room every break taken during the study period. It is necessary to consider that the performance of the brain is very sensitive to the level of oxygen, that is why the air in the room should be renewed regularly.

In relation to the color of the walls of the study space, color produces exciting experiences that impact on learning and creativity, since they produce visual stimulation, in this sense, red, yellow and orange colors increase brain activity; green, blue and violet, generate relaxation; white motivates us to order; red awakens motivation and interest; yellow is related to objectives and goals. On the other hand, according to Toca Sociales (2021), dark colors are related to difficulties, impediments and weaknesses, while green inspires to find solutions and leads to calm, therefore, a combination of blue, white and green colors would be the ideal colors for the study space.

According to Beltrán (2021), the furniture in the study area should have a table or desk large enough to be able to use all the necessary materials, such as books, computer, and with enough space to write and not have clutter; it should be proportional to the student's height and give him/her space to stretch his/her legs. The combination of an adequate chair and desk will make a clear difference in the comfort of studying and will help to have a good posture. In this sense, it is recommended that the student's chair be in such a way that it allows the student's spine to be correctly positioned (ergonomic), as for the seat, it should allow the student to move easily and achieve a comfortable posture. Likewise, the chair should have the facility to regulate the height and backrest, which should preferably be somewhat curved to support the lower back well and not have pain in the spine in the lumbar area, since the best way to sit should be with the back and legs straight, feet on the floor and head slightly tilted, keeping a distance of approximately 30 cm. Regarding the work table, Compartir palabra maestra (2022) points out that it should allow an inclination of about 20 degrees, thus, the reading level will be better and more comfortable. It is also recommended to have shelves where books and notebooks can be organized so that they can be available for use. Other recommendations point out that a blackboard or cork board should be available, since it is possible to make notes, pending, chronograms, at sight, and that, although it is a custom of yesteryear, it is better than forgetting them because they are stored in a digital device (Toukoumidis, 2017).

Multifamily Units

Regarding the right to housing, the Political Constitution of the United Mexican States mentions in its paragraph 70, article 4: "Every family has the right to enjoy a decent and dignified housing" (Political Constitution of the United Mexican States, 06/06/2023). For its part, the Housing Law states in Article 2, "It will be considered dignified and decent that which complies with the applicable legal provisions on human settlements and construction, health, has habitable and auxiliary spaces, as well as basic services and provides its occupants with legal security regarding their ownership or legitimate possession, and contemplates disaster prevention criteria and the physical protection of its occupants from potentially aggressive natural elements" (Ley de Vivienda, 14/05/2019).

ISSN: 2523-2428

For its part, the World Health Organization (WHO) states "A healthy dwelling is a shelter that fosters a state of complete physical, mental and social well-being. Healthy housing provides a sense of home, and a sense of belonging, security and privacy. Healthy housing also refers to its physical structure and the extent to which it supports physical health, including by being structurally sound; providing shelter from inclement weather and excess moisture; and providing comfortable temperatures, adequate sanitation and lighting, sufficient space, safe fuel or power connection, and protection from pollutants, trauma risks, mold, and pests" (Pan American Health Organization, 2022).

With respect to recommendations for housing construction, Pérez (20025), quoted by Verdugo (2021), considers that in Mexico these provisions have not been respected since many precarious urbanizations have been carried out, in search of a better commoditization of urban goods and industrial production in a massive way to be occupied by low-income families. This was originated by the great demand for housing since the eighties in our country, which has been offering housing with only one bedroom, no corridors or outdoor circulation areas, so that generate psychological stress, overcrowding and deterioration, their materials are of poor quality in addition to not giving proper protection to their tenants.

In the case of multi-family dwellings, these can measure from 28 to 50 square meters. This type of housing is acquired in some cases by employees affiliated with the Mexican Social Security Institute (IMSS), the Housing Fund of the Institute of Security and Social Services for State Workers (FOVISSTE), the Pension Institute of the State of Jalisco (IPEJAL), the National Housing Fund Institute for Workers (INFONAVIT) or also by independent workers or unregulated trades, whose income is low or irregular, thus giving very little option to the popular sectors. There are also homes that range in size from 36 to 55 square meters. According to Maya and Maycotte (2011), cited by (Galeana and Maya, 2020), this group of dwellings constitute the type of mass housing, under the precepts of commoditization based on the generation of new housing.

In this order of ideas, according to Housfy blog (2020), governments form a kind of neighborhoods of social interest housing, locating all these households in the same place through horizontal buildings, sometimes called multifamily. The distribution of these homes, according to Dávila (2017), is very simple, normally in the interior there is a space that functions as a dining room and transit area, a small kitchen, a small bathroom, a bedroom or two, where barely fits a double bed, not having work areas, hygiene, transit, or storage; the location of the doors and windows does not provide for proper cross ventilation, likewise, does not meet the optimal characteristics of sunlight and natural lighting and sufficient and its dimensions are the minimum established by building regulations.

It is important to note that in the municipality of Guadalajara there are around 393,530 houses with a surface area of less than 60 square meters and 12,000 micro-houses (huevito) with surfaces of around 40 square meters (MURAL, 2020).

Objective of the research

The objective of this research is to "Establish the relevance of housing located in multifamily units in the municipality of Guadalajara for learning at home, through the analysis of the relationship between space and study".

Methodology

In order to carry out this objective, a mixed approach research was conducted, based on the description of situations, places, digital and documentary texts (Hernández, et al, 2014). The procedure was as follows:

a) For the collection of information, digital documents and real estate information were reviewed through the internet.

b) The research was of the documentary and informative type, since this type allows showing relevant information on a specific topic that comes from different information sources. Bibliographic cards were used as an instrument.

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In this research only the so-called family units of the municipality of Guadalajara were taken into account, which yield the number of 56 in total according to the Government of Guadalajara (2017), but when searching for information on the internet we found that this is very scarce, since no information appears for the 56 housing units corresponding to the municipality of Guadalajara. Given this reality, we proceeded to calculate the number of the sample, in addition, to give us the minimum acceptable percentage of reliability, giving us a result of 17 housing units with 85% reliability.

Procedure

First, the 17 housing units were located on Google Maps, which are shown in Figure 1. Subsequently, information on the housing units located in these multifamily units was searched on the web to identify their spatial characteristics, among others.

Results

Housing units in Guadalajara (see Figure 1).

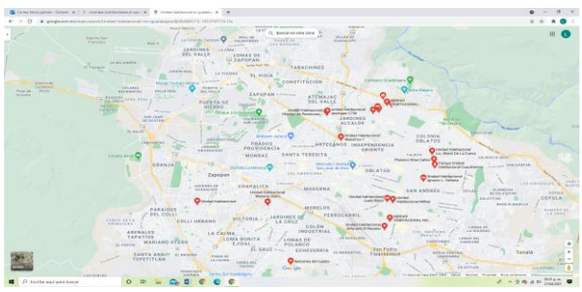

Figure 1 Location of housing units in the municipality of Guadalajara
Source: Google maps (2023).

Nº	Housing Unit	Address
1	Infonavit Estadio A.C.	Calzada Independencia Norte.
2	Mariano Otero	Avenida Mariano Otero
3	Javier Mina	Andador Javier Mina
4	Infonavit El Rosario	Calle Río Juárez 1906
5	Fovissste Estadio C9	Avenida Patria 127
6	Independencia	Código 44240
7	Planetario verde	Col Habitacional el Verde
8	El Sauz	Calle Isla Gomera
9	Rancho Nuevo	Colonia Rancho Nuevo
10	Fovissste Estadio	Calle Monte Rosas
11	San Eugenio Oblatos	Oblatos
12	Colón	Calle Isla Socorro No 2018.
13	Clemente Orozco	Av. Patria 3732
14	Plutarco Elías calles	Av. Plutarco Elías Calles
15	Miravalle Infonavit	Av. Artes Plásticas
16	San Eugenio	Col San Eugenio
17	San Rafael	Calle Federico Medrano

Table 1 Housing units in the municipality of Guadalajara
Source: Own elaboration

No.	Housing Unit	Dimensions Mts2.	Living-dining room	No. of bedrooms	Bathrooms	Kitchen
1	INFONAVIT Estadio A.C.	53	1	2	1	1
2	Mariano Otero	51	1	2	1	1
3	Javier Mina	40	1	2	1	1
4	INFONAVIT El Rosario	54	1	2	1	1
5	FOVISSSTE Estadio C9	54	1	2	1	1
6	Independencia	78	1	3	1	1
7	Planetario verde	60	1	3	1	1
8	El Sauz	62	1	2	1	1
9	Rancho Nuevo	61	1	2	1	1
10	FOVISSSTE Estadio	54	1	2	1	1
11	San Eugenio Oblatos	63	1	2	1	1
12	Colón	53	1	2	1	1
13	Clemente Orozco	56	1	2	1	1
14	Plutarco Elías Calles	50	1	2	1	1
15	Miravalle INFONAVIT	60	1	2	1	1
16	San Eugenio	63	1	2	1	1
17	San Rafael	54	1	2	1	1

Table 2 Characteristics of the housing units in the housing units of the municipality of Guadalajara.
Inmuebles24.com (2020), 2. Google.com (2021), 3. Casas Mitula.com (2021), 4. Inmuebles24.com (s/f), 5. Propiedades.com (2019). Lamudi.com (n/d), 7. Inmuebles24.com (2020), 8. Bienes Online.com (2020), 9. Propiedades.com (2023). 10. Propiedades.com (2023). Lamudi.com (2023), 12. Bienes Online.com (2019), 13. Inmuebles24.com (2020), 14. Inmuebles.com (2020), 15. Bienes Online.com (2023), 16. Propiedades.com (2021), 17).

After obtaining the data from the 17 housing units, the average size of the houses was obtained, as well as the average number of bedrooms. In the case of bathrooms and living-dining room, all the houses have a bathroom and living-dining room together, the results are (see Table 3):

17 housing units			Municipality of Guadalajara	
Average dimensions	Living-dining room	No. Bedrooms	Bathrooms	Kitchen
57.17 m^2	1	2	1	1

Table 3 Average housing dimensions and number of bedrooms, kitchen, bathroom and living/dining room
Source: Own elaboration.

Distribution of a multifamily housing unit, with the purpose of identifying the spaces and distribution, in which an average of 5.6 people live in each dwelling (Chong, n.d.).

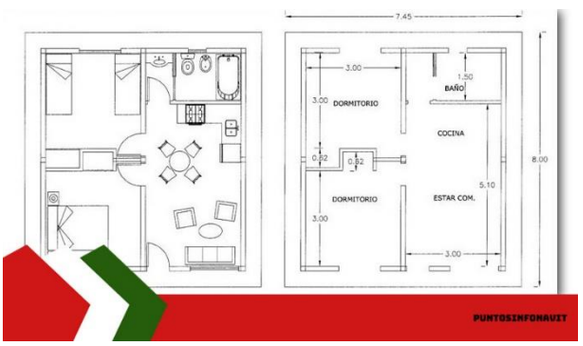

Figure 2 Average housing dimensions and number of bedrooms, kitchen, bathroom and living/dining room
Source: Puntos INFONAVIT (n/d).

ISSN: 2523-2428

Conclusions

Population growth in the municipality of Guadalajara during the last decades brought with it the need for new housing, with low-income families being the main demanders. In response to this situation, the municipal government of Guadalajara implemented financing programs for the acquisition of low-income housing in the 1970s. These programs were open to people earning at least four minimum wages. This is how the so-called multi-family units came about, which were built without respecting the recommendations and requirements for decent housing. These homes have an area of around 40 and 60 square meters, which include: living-dining room, 2 bedrooms, 1 bathroom and kitchen, all of these spaces with minimal dimensions. In addition, it is observed that they do not have spaces for study, work or rest. In terms of occupancy per dwelling, an average of 5.8 people live in each dwelling, so that each space in the house is occupied by one or two family members continuously.

Regarding spaces for relevant academic learning, different authors recommend that for a student to achieve a good performance in their study activities, the home must have a specific place, in which to reaffirm the knowledge acquired at school and acquire new ones, for this, that space must be isolated from the rest of the house and the family, have good lighting, ventilation, no noise and quiet, in this sense it is concluded that the housing units of the municipality of Guadalajara do not have any of these features, which are essential for the student to perform their extracurricular activities at home, In this sense, it is concluded that the housing units in the municipality of Guadalajara do not have any of these characteristics, which are fundamental for the student to carry out his extracurricular activities at home, therefore, the student will carry out his activities at the dining table or in the living room or will end up lying in bed trying to do them, besides always being in the company of some of his family members. This lack of space and environment conducive to learning will ultimately result in poor school performance, which will influence the student's decision to continue studying.

Funding

The present work has not been financed by any entity.

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ISSN: 2523-2428

Article **Journal Civil Engineering**
December 2023, Vol.7 No.18 11-21

Economic valuation of the proper management of municipal solid waste in an educational space

Valuación económica del manejo adecuado de los residuos sólidos urbanos en un espacio educativo

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DOI: 10.35429/JCE.2023.18.7.11.21 Received July 20, 2023; Accepted December 30, 2023

Abstract

The correct management of Municipal Solid Waste (MSW) in any population center is essential to guarantee the quality of life of its inhabitants and the surrounding environment. The study carried out involved the quantification of MSW generated in specific areas of the Juan Pablo II campus of the University of Guanajuato, with the use of two complete recycling stations with primary and secondary labeling, graphically specifying a subclassification with infographic type posters. For 5 weeks we separated and sold the most commercially valuable solids in Celaya, delivering the proceeds to the corresponding university agency, and the lids of the different food containers were donated to an association that supports children with cancer. With the amount obtained, an economic feasibility analysis was carried out using the financial evaluation criteria Net Present Value (NPV) and Internal Rate of Return (IRR) to know the feasibility in monetary terms; to complement this, the equilibrium point (Q) and the sensitivity analysis were used; trying to exploit the maximum recycling capacity and move to the circular economy.

Economic feasibility, Municipal solid waste, Circular economy

Resumen

El manejo correcto de los Residuos Sólidos Urbanos (RSU) en cualquier centro de población es indispensable para garantizar la calidad de vida de sus habitantes y del ambiente circundante. El estudio realizado, implica la cuantificación de los RSU generados en áreas específicas de la sede Juan Pablo II de la Universidad de Guanajuato, con el uso de dos estaciones completas de reciclaje adecuadas con una rotulación primaria y secundaria, precisando gráficamente una subclasificación con carteles tipo infografía. Durante 5 semanas se llevó a cabo la separación y venta de los sólidos valorizables más comercializados en Celaya; entregando lo recaudado a la instancia universitaria correspondiente, aunado las tapas de los diferentes envases alimenticios fueron donadas a una asociación que apoya a niños con cáncer. Con el monto obtenido se realizó un análisis de factibilidad económica utilizando los criterios de evaluación financiera Valor Presente Neto (VPN) y Tasa Interna de Retorno (TIR) a fin de conocer la viabilidad en términos monetarios; para complementar se utilizó el punto de equilibrio (Q) y el análisis de sensibilidad; intentando explotar la capacidad de reciclaje máxima y transitar a la economía circular.

Viabilidad económica, Residuos sólidos urbanos, Economía circular

Citation: MORENO-MARTÍNEZ, Viridiana, PALACIOS-HERNÁNDEZ, Otoniel, MORENO-MARTÍNEZ, Jatziri Yunuén and GALVÁN-CHÁVEZ Arturo. Economic valuation of the proper management of municipal solid waste in an educational space. Journal Civil Engineering. 2023. 7-18:11-21.

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Introduction

The increasing volume and complexity of waste associated with the modern economy is posing a serious risk to ecosystems and human health. Poor waste management (ranging from non-existent collection systems to inefficient disposal) leads to air, water and soil pollution. Open and unsanitary landfills contribute to the contamination of drinking water and can cause infections and transmit diseases (United Nations Environment Programme, 2023).

"Don't waste to avoid scarcity". This old adage has much validity as world leaders, as well as local communities, increasingly call for an amendment to the so-called "throwaway culture" (World Bank, 2018). One of the solutions to this problem comes through recycling, where the aim is to convert some of the materials that make up waste into materials that can be reused in production processes. From an environmental and public health point of view, the proper management of waste in the stages following its generation allows mitigating its negative impacts on the environment and health, in addition to reducing pressure on natural resources (Secretaría de Medio Ambiente y Recursos Naturales, 2017a).

It is undeniable that there is economic importance in MSW, but it is directly conditioned by the correct separation of these, if done successfully, it transitions to the circular economy; Belda Hériz (2018) defines that the circular economy intends that our products are always in circulation, not only extending its useful life but getting that, both during this, and once it is over, they serve to generate new products, so that it is not necessary to extract large amounts of natural resources, but to use again those that were already once used or extracted, thus avoiding so much dependence.

The Universidad de Guanajuato in its different campuses is committed to primary and to some extent secondary separation, although it is imperative to point out that there is a disproportionate rate of waste generation, as well as little culture of integral separation.

The reason for carrying out this study, by sampling the MSW generated at the Juan Pablo II Campus of the Celaya-Salvatierra Campus of the University of Guanajuato in key areas, is to find out the patterns in the composition of the waste, quantify the valuable waste and look for an economic return by selling it in collection centres. The aim is to show the community that it is possible to move towards circularity, without separation being considered an unacceptable economic practice in the environment, but rather as an urgent necessity in the face of environmental deterioration.

Municipal solid waste

A waste is the "part or portion that is left of a whole" (Rondón Toro et al., 2016), municipal solid waste (MSW) is the waste generated in households, resulting from the disposal of the materials used in their domestic activities, the products they consume and their containers, packaging or wrapping; as well as waste from any other activity within establishments or on public roads that generates waste with household characteristics, and waste resulting from the cleaning of roads and public places (Secretaría de Medio Ambiente y Recursos Naturales, 2017c).

According to the World Bank report What a Waste 2.0, 2010 million tonnes of municipal solid waste is generated annually worldwide, and at least 33% of it is not managed without risk to the environment (World Bank, 2018). In Mexico according to INEGI in 2018, an average of 107,056 tons of rubbish were collected daily, that is, 854 grams per person; the state of Guanajuato ranks sixth, with a generation of 4,481 tons daily, contributing 4.2 % of the total generation (Instituto Nacional de Estadística, Geografía e Informática, 2019). Particularly, in the municipality of Celaya, Turcott and Aguilar (2020) indicate that 0.78 kilograms of waste are generated per inhabitant per day, highlighting that there is 96% coverage in the collection service.

Reuse and recycling simultaneously reduce the use of energy and water needed for extraction and processing, as well as the need for space to finally dispose of the waste. From an economic point of view, a lower volume of waste requiring final disposal reduces operating costs; according to OECD estimates (Secretaría de Medio Ambiente y Recursos Naturales, 2017a).

ISSN: 2523-2428

Municipal solid waste management

In 2015, 17 Sustainable Development Goals (SDGs) were created in an effort to move towards a reconciliation between human lifestyles and the planet, with 15-year targets that allow us to continue to thrive as a species, but with the least possible environmental impact. Goal 12: Ensure sustainable consumption and production patterns and its target 12.5: By 2030, significantly reduce waste generation through prevention, reduction, recycling and reuse (United Nations, 2022), state the need for proper MSW management.

Providing integrated MSW management in Mexico is based on the Political Constitution of the United Mexican States; the General Law on Ecological Balance and Environmental Protection; the General Law for the Prevention and Integrated Management of Waste and its regulations (Government of Mexico City, 2023); as well as multiple regulatory instruments at the federal, state and municipal levels.

For the state of Guanajuato, the legal instruments are extensive; in particular, there is the Good Housekeeping Practices label, which is a model promoted by the Environmental and Land Management Office, which promotes the participation and responsibility of society to improve environmental performance and reduce the impact of the effects of climate change. It is aimed at micro, small businesses, business chambers, service providers, the tourism industry and public (such as the University of Guanajuato) and private institutions; it is a set of actions or activities that allow the reduction in the use of natural resources such as energy, water, waste generation, environmental risks, consumption of resources and raw materials (Procuraduría Ambiental y de Ordenamiento Territorial de Guanajuato, 2023).

For Mexico, basic MSW management still predominates, which consists of collecting and disposing of waste in sanitary landfills, wasting waste that can be reincorporated into the productive system (Secretaría de Medio Ambiente y Recursos Naturales, 2017b); this is the responsibility of the municipality.

Toledo Cervantes and Quintero Castellanos (2022) show that the problems they essentially face are budgetary control, the absence of operating manuals and technical expertise, resulting in a profound ambiguity in the definition of MSW policy and its management. In addition, there is little or no culture of waste separation at source.

Economic value of municipal solid waste

The general economic definition of waste "is something that has no use value, and therefore no exchange value. Moreover, because waste is a nuisance, we are willing to pay to be rid of it" (André and Cerda, 2006).

MSW generates a considerable expense for municipalities, the costs of waste collection reported in the PPGIR (Programmes for the Prevention and Integral Management of Waste) corresponding to 167 municipalities in 13 federal entities; they amount on average to $434.03. 03 per tonne collected and only consider the operation of the collection service; in the case of the costs for final waste disposal, reported by 84 municipalities in 10 states, they indicate an average cost of $121.58 per tonne deposited in the final disposal sites (including only the salary of the workers who work at the site and the fuel for the machinery used), according to the Ministry of Environment and Natural Resources, (2020).

The economic activity that is linked to the use of municipal solid waste in Mexico is known as "pepena". Generally, these groups do not carry out their activities in a hygienic manner, nor with the appropriate equipment, nor do they adhere to labour legislation, nor do they pay taxes or have social security. Among them, there are often minors and elderly people who are exposed to various diseases, infections and contagions (Pineda Pablos and Loera Burnes, 2007). This is why it is not considered a widely accepted job in society, but this does not imply that it is poorly paid compared to other informal or even formal jobs. A pepenador or pepenadora in Mexico can earn from $350.00 to $1,800.00 pesos per day collecting rubbish, according to information from NTR, a website from Zacatecas, which interviewed people who work in this trade. (Grupo Fórmula, 2022).

ISSN: 2523-2428

Generalising, we can consider and model as an ongoing business the integrated management of MSW, with primary and secondary separation, for the subsequent sale of the recoverable waste and thus reduce the amount that reaches final disposal. Given that there is an economic value and a market for MSW, of course undervalued in Mexico, the study seeks to evaluate the economic feasibility of integrated waste management within a given area at the Juan Pablo II campus of the Celaya-Salvatierra Campus of the University of Guanajuato.

Research design

Solid urban waste generated during 5 weeks of the January-June 2023 semester was collected, separated and quantified in the cafeteria area and the Civil Engineering laboratory building of the Juan Pablo II campus of the Celaya-Salvatierra campus, belonging to the University of Guanajuato. Two complete recycling stations were used, with primary and secondary separation signage, poster type in a visual range for any user (Figures 1, 2 and 3) being: organic, non-recyclable inorganic, PET, non-PET plastic, glass, cans, paper and cardboard; in addition to providing a description of each type, conditions for their deposit and examples of these wastes.

Figure 1 Organic and inorganic container

Figure 2 PET Container

Figure 3 Non-PET plastic, paper and cardboard, glass and cans containers

During the days of the study, the waste from both stations was collected in the afternoon, re-sorting those deposited incorrectly, and then throwing away liquids or any other solid waste that did not belong to the recoverable containers. After weighing, they were transported to a temporary warehouse awaiting a larger quantity to be sold at a collection centre close to the institution. The selected facility was REPLAFI, Recicladora de Plásticos y Fibras del Bajío, located at Paseo de San Nicolás de Parra, Lagos, 38060 Celaya, Gto. approximately 2.5 kilometres away with an estimated time of 4 minutes by car (Figure 4).

ISSN: 2523-2428

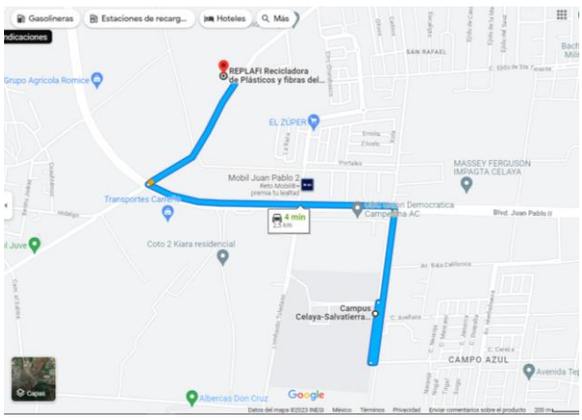

Figure 4 REPLAFI
Source: (Google Maps, 2023)

The money collected from the sale was handed over in its entirety to the Campus Sustainability Management Liaison, as well as the receipts issued by the collection centre; a document necessary to keep the Good Housekeeping Practices Distinction, in verification aspect three: Responsible use of Materials and Inputs, Reduction in waste generation; issued by the Environmental and Land Management Office (PAOT) of the State of Guanajuato.

Methodological considerations

The weights recorded are composed exclusively of what was collected in the containers of the two recycling stations, leaving out sanitary waste, those that were highly contaminated by other waste (due to difficult cleaning and sale) or that did not belong to the designated categories; Sampling was carried out from Monday to Friday, observing official suspensions. Sanitary precautions were implemented for the handling of MSW with the volunteers, such as: polyurethane-coated nylon gloves, lab coat and antibacterial gel. An electronic scale with an accuracy of 0.05 kg, provided by the Civil Engineering laboratories of the Celaya-Salvatierra Campus, was used for weighing.

The caps of the PET, glass or other bottles found were not quantified for sale, with the opportunity to donate them to a support centre for children with cancer that helps in the city of Celaya. This reduced on average 14.12% of the total weight of the PET type container, as for a 0.5 litre bottle with a weight of 17 grams the cap weighs approximately 2.4 grams according to Remsa plásticos (2023).

Financial evaluation

a) Net Present Value (NPV)

The first financial evaluation criterion to be used is the Net Present Value (NPV), which is a practical method, because future expenditures or inputs are transformed into monetary units of the current equivalent rate considered, in the present (Arbones Malasani, 2009). The NPV is the monetary amount resulting from the difference between the net income derived from the sale of the present value of the valuables and the initial investment in inputs and materials:

$$VPN = \sum_{n=0}^{N} \frac{A_n}{(1+i)^N} = \sum_{n=0}^{N} \frac{A_n}{(1+TREMA)^N} \quad (1)$$

Where:

VPN = Net Present Value

A_n= net cash flow at the end of the period

i = TREMA TMinimum Acceptable Return Handle

N= service life of the project

Source: (Moreno-Martínez et al., 2022).

A positive NPV indicates that the present value of the net income fully covers the cost of the investment; a negative NPV means that the present value of the net income does not cover the cost of the initial investment (Alvarado Verdín, 2015).

a) Internal Rate of Return (IRR)

The second criterion to be used is the Internal Rate of Return (IRR), defined as the interest rate that makes the net present value equal to zero, i.e. when the TREMA is equal to the IRR (Vidaurri Aguirre, 2013), to deduce it we follow the method of trial and error or iteration, until converting the NPV to zero, mathematically (Moreno-Martínez et al., 2022):

$$\boldsymbol{VPN = \sum_{n=0}^{N} \frac{A_n}{(1+TREMA)^N} = 0} \quad (2)$$

When IRR > TREMA the alternative is accepted, if IRR = TREMA the alternative is reconsidered and if IRR < TREMA the alternative is rejected. (Alvarado Verdín, 2015).

a) Sensitivity analysis

Economic analysis uses estimates of future values of a parameter to help make decisions; which is the objective of this study, to identify possible scenarios for action. Therefore, performing a sensitivity analysis to visualise the effect of variation in the amount of recoverable MSW, its market price or TREMA becomes relevant. Sensitivity analysis determines how a value measurement is altered when one or more parameters vary over a certain range of values. Usually one parameter is varied at a time, and independence from other parameters is assumed (Blank and Tarquin, 2011).

b) Equilibrium point

For the purpose of deepening and providing a broader picture of the research, it is necessary to resort to the determination of the break-even point, as Blank and Tarquin (2011) show, this analysis finds the value of a parameter that makes two elements equal, it is determined from mathematical equations, such as the revenues and costs of a product, the supply of materials, and supply and demand parameters:

$$Q = \frac{CF}{r-v} \tag{3}$$

Where:

Q = equilibrium quantity

CF = fixed costs

r = revenue per unit

v = variable cost per unit

Knowing Q, aims to illustrate how the market for the sale of recoverable MSW in the city of Celaya works and to detect areas of opportunity.

Financial considerations

The financial generalities applicable to the study are described below:

Useful life

The weighing of recoverable MSW in the 5 weeks for calculation purposes translates to one month, given that it is only monitored from Monday to Friday and respecting official suspensions.

The useful life of project N is proposed at 20 months, which would be equivalent to 2 school years, given that there are 2 holiday periods and days off, as well as any other setbacks. In addition, as it is a pilot test that may or may not be continued.

Income

For the income per kilogramme of recoverable MSW, the average purchase price on the days on which it was taken to the collection centre (at the end of each week) was used, as it was noted that there were fluctuations in the amount received per kilogramme from one week to the next.

Expenditure

Among the expenditures considered are the initial investment in gloves, posters and containers, which appeared to be a new acquisition, but these were already in the possession of the infrastructure department, where the purchase price and the length of time they were stored are unknown. As monthly expenses, gasoline and ecological bags. Since the fieldwork was carried out by students and teachers who voluntarily wished to join the project, the applicable salaries and taxes are omitted, as well as the depreciation of the containers and the vehicle for transport.

Choice of the TREMA

For the calculations of the financial evaluation, a TREMA equal to the one-month (28-day) Certificados de la Tesorería de la Federación (CETES) rate of 11.25 % as of 14 September 2023 (Secretaría de Hacienda y Crédito Público, 2023) is assumed. As this is an investment rate considered to be safe.

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Results and discussion

The initial investment that simulated the acquisition of the two recycling stations and other materials was $15,897.85 and the monthly operating expenses amounted to $42.01 as shown in Table 1.

a) Initial investment	Quantity	price	Total
50 gallon container	1	$3,388.00	$3,388.00
Eco bottle	1	$4,516.37	$4,516.37
Recycling station	2	$3,702.74	$7,405.48
Nylon gloves (pairs)	6	$68.00	$408.00
Signs	12	$15.00	$180.00
Total			$15,897.85
b) Monthly income	**Quantity**	**price**	**Total**
Ecological bags	120	$0.11	$13.64
Petrol (km travelled)	10	$2.84	$28.37
Total			$42.01

Table 1 General expenditure of the investment project

From the sale of recoverable MSW, a total of $339.53 pesos was obtained (Table 2), with the PET container collecting the highest amount of $156.96, while the heaviest weight collected was cardboard with 42.86 kg, for a total of 98.88 kg (Table 3).

	kg	Price	Income
PET	19.62	$8.00	$156.96
Latas	2.12	$18.00	$38.16
Cartón	42.86	$0.50	$21.43
Papel	30.24	$4.00	$120.96
Vidrio	4.04	$0.50	$2.02
Total income/month			$339.53

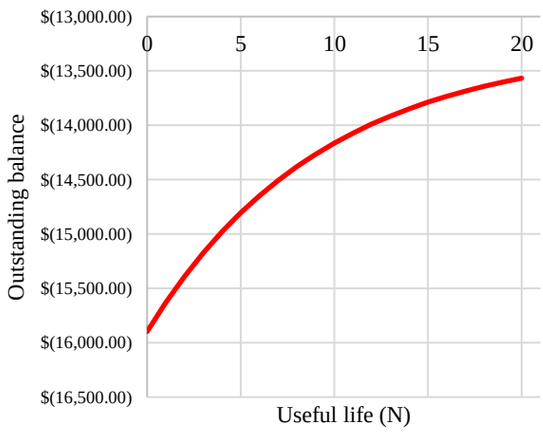
Table 2 Total income from the sale of recoverable MSW

For the calculation of the cash flows in period N= 0 the initial investment was used, from periods 1 to 20 the difference of the total income and expenditure per month was obtained; when calculating the sum of the PV it shows an unfavourable behaviour with a value of -$13,566.81 < 0, consequently, the IRR exhibits a rate of -7.96% < TREMA, the outstanding balance was calculated herewith (Table 3);

Both criteria show that an investment in these conditions should be rejected, as the initial expenses are disproportionate in consideration of the monthly income (in the case of not having the containers previously, such as those that were loaned for the study); while the outstanding balance corroborates this, because after the useful life (N=20) there is no positive balance, $13,566.81 is still owed; this behaviour is exemplified in Graphic 1.

N	Cash flow	TREMA	VP
0	-$15,897.85	11.25%	-$ 15,897.85
1	$297.52	11.25%	$ 267.43
2	$297.52	11.25%	$ 240.39
3	$297.52	11.25%	$ 216.08
4	$297.52	11.25%	$ 194.23
5	$297.52	11.25%	$ 174.59
6	$297.52	11.25%	$ 156.93
7	$297.52	11.25%	$ 141.06
8	$297.52	11.25%	$ 126.80
9	$297.52	11.25%	$ 113.98
10	$297.52	11.25%	$ 102.45
11	$297.52	11.25%	$ 92.09
12	$297.52	11.25%	$ 82.78
13	$297.52	11.25%	$ 74.41
14	$297.52	11.25%	$ 66.88
15	$297.52	11.25%	$ 60.12
16	$297.52	11.25%	$ 54.04
17	$297.52	11.25%	$ 48.58
18	$297.52	11.25%	$ 43.66
19	$297.52	11.25%	$ 39.25
20	$297.52	11.25%	$ 35.28
TIR	-7.96%	VPN	-$ 13,566.81
Outstanding balance			-$ 13,566.81

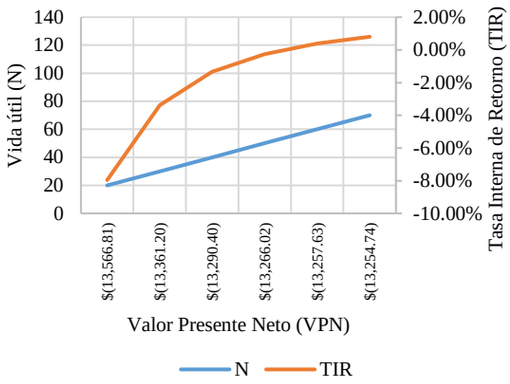
Table 3 Calculation of NPV, IRR and outstanding balance



Graphic 1 Outstanding balance of the project over time

Since the behaviour is unfavourable, the sensitivity analysis can show the variables that have more or less impact; it was decided to use as a comparative parameter the NPV with respect to an increase in the useful life of the project from 20 months to 70 months (2 to 7 school years). Consequently, the IRR shows changes, which can be seen in the sensitivity graph (Figure 2).

ISSN: 2523-2428



Graphic 2 NPV vs. N and IRR sensitivity analysis

The sensitivity curves indicate that the time N is not sensitive, i.e. despite increasing the useful life of the project considerably, the NPV does not move, as it only decreases by $312.07, while the IRR indicates sensitivity, going from -7.96% to 0.8003% (Table 4).

N	VPN	TIR
20	-$ 13,566.81	-7.96%
30	-$ 13,361.20	-3.38%
40	-$ 13,290.40	-1.34%
50	-$ 13,266.02	-0.26%
60	-$ 13,257.63	0.3881%
70	-$ 13,254.74	0.8003%

Table 4 Calculation of NPV and IRR with increasing N

If the market for recoverable MSW continues to behave with the same average purchase prices (r) that were collected during the time of sale, it is possible to use the break-even point (Q) to know how many kilograms approximately need to be collected and sold in the same originally budgeted useful life (20 months), amounting to 3,700.87 kg per month (Table 5); under the same conditions, the fixed costs (FC) were distributed over the useful life of the project (20 months) and the monthly costs for petrol were added. It is necessary to indicate that the variable costs per unit (v) were disregarded as they are minuscule.

	Q	CF	r
PET	155.50	$823.27	$8.00
Cans	46.49	$823.27	$18.00
Cardboard	1646.53	$823.27	$0.50
Paper	205.82	$823.27	$4.00
Glass	1646.53	$823.27	$0.50
Total	3700.87		

Table 5 Calculation of break-even point Q (kg)

Favourable scenario

While conducting the study, it was possible to observe that students mostly ignored the signs and posters; they preferred to deposit their waste in the wrong container or in other containers outside the two service stations, some of them located continuously, these circumstances provide an area of opportunity. Again using the expression of the break-even point (Q) and the revenue per unit (r), an idealisation of these two parameters was carried out, reinforced by the viva voce expressions made by the workers of the collection centre, where they indicated the highest value of the purchase prices at which all the recoverables have been maintained (Table 6).

	Kg	Price	Income
PET	65	$15.00	$975.00
Cans	15	$22.00	$330.00
Cardboard	84	$3.00	$252.00
Paper	60	$8.00	$480.00
Glass	15	$3.00	$45.00
Total income/month			$2,082.00

Table 6 Idealisation of the purchase price and kilograms harvested

With the data obtained and simulating a favourable scenario, the NPV and IRR were recalculated, with the same useful life and TREMA, visualising in Table 7 that the NPV increases to $85.22 > 0, the same happens with the IRR, which acquires a value of 11.33% > 11.25% just above the safe investment rate.

N	Cash flow	TREMA	VP
0	-$15,897.85	11.25%	-$ 15,897.85
1	$2,039.99	11.25%	$ 1,833.70
2	$2,039.99	11.25%	$ 1,648.27
3	$2,039.99	11.25%	$ 1,481.59
4	$2,039.99	11.25%	$ 1,331.77
5	$2,039.99	11.25%	$ 1,197.09
6	$2,039.99	11.25%	$ 1,076.04
7	$2,039.99	11.25%	$ 967.23
8	$2,039.99	11.25%	$ 869.42
9	$2,039.99	11.25%	$ 781.50
10	$2,039.99	11.25%	$ 702.47
11	$2,039.99	11.25%	$ 631.43
12	$2,039.99	11.25%	$ 567.58
13	$2,039.99	11.25%	$ 510.19
14	$2,039.99	11.25%	$ 458.59
15	$2,039.99	11.25%	$ 412.22
16	$2,039.99	11.25%	$ 370.53
17	$2,039.99	11.25%	$ 333.06
18	$2,039.99	11.25%	$ 299.38
19	$2,039.99	11.25%	$ 269.11
20	$2,039.99	11.25%	$ 241.90
TIR	**11.33%**	**VPN**	**$ 85.22**

Table 7 Calculation of NPV and IRR idealising income

ISSN: 2523-2428

Donation of lids

Donating caps from various disposable containers to associations that help children with cancer, whose families are unable to afford treatment, allows the circular economy to continue. Mexico is among the countries that produce the largest amount of polyethylene terephthalate (PET), due to the high consumption of soft drinks and bottled water. It is estimated that 200 PET bottles are produced per year for every Mexican (Comisión Nacional de Áreas Naturales Protegidas, 2018). After completing the sampling time, 3.06 kilograms (Table 8), approximately 1,530 caps, were collected and separated by colour, which were donated to the Asociación Mexicana de Ayuda a Niños con Cáncer (AMANC), as part of the "Destapando Esperanza" Campaign at the Celaya collection centre, located at Calle Presa de la Amistad #111, Colonia Buenfil, Celaya, Guanajuato.

Color	Weight (Kg)
Blue	0.95
Red	0.72
White and transparent	0.71
Yellow and gold	0.21
Other colours	0.47
Total	3.06

Table 8 Collected lids

Acknowledgement

To the Liaison for Sustainability Management of the Celaya-Salvatierra Campus, University of Guanajuato.

Conclusions

The results found, unfortunately, show that the university community at the Juan Pablo II Campus did not respond as expected, due to the behaviour they showed when depositing waste, without separating it and ignoring the recycling stations; this indicates that users are not willing to follow an integrated MSW management plan. This had an impact on the amount of recoverable waste and therefore on the amount of waste collected at the end of the sampling period.

The financial analysis is highly unfavourable, it is not even close to being considered an investment that would allow for large-scale implementation, since the NPV was equal to -$13,566.81 and the IRR was -7.96%. It must be stressed that the purchase prices of marketable products are low, and even from one week to the next it was observed that they were declining. In Mexico, as in other Latin American countries, "pickpocketing" is a stigmatised economic activity, an idea that is probably shared by the student community, hence probably the attitude visualised in the study.

In an attempt to generate a favourable scenario for the future, it was simulated to estimate a greater amount of recoverable waste in the different categories of MSW, as well as to expect an increase in the purchase price of MSW; at least to achieve a NPV greater than zero and compensate the initial investment by going from a monthly income of $339.53 to $2,082.00. Although it requires a huge effort from all involved, this could be the opportunity to establish a circular economy model that transcends the school space into everyday life. This effort should be underpinned by the creation of new legal instruments on environmental issues, to try to eradicate the inefficiency and lack of knowledge on the proper management of MSW; directly related to the number of available containers, adequate labelling, collection periods, but especially to education on the issue of separation, which is not higher at higher educational levels, according to what was observed during the study.

Despite the fact that a business model such as the one analysed is not financially feasible, efforts should not cease in order to continue strengthening integrated MSW management programmes, the value of change is there, only disguised as hard work and apparently without economic retribution.

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ISSN: 2523-2428

Article **Journal Civil Engineering**
December 2023, Vol.7 No.18 22-30

Design and construction of modular panel prototype replacing unicel with the reuse of cardboard

Diseño y construcción de prototipo de modular panel sustituyendo el unicel por la reutilización del cartón

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DOI: 10.35429/JCE.2023.18.7.22.30 Received July 25, 2023; Accepted December 30, 2023

Abstract

Self-construction is a scenario that frequently occurs within the construction field. The purpose of this project is to reduce cardboard waste, giving it a second use and also reduce the cost of construction, mainly in the self-construction field. As a result of an exhaustive investigation about the history of panel and its main component material, which is polystyrene, the environmental impact that its use (polystyrene) represents is considered, which is why the replacement of polystyrene is proposed, for a material that completely reduces or mitigates this contamination problem, taking into account the characteristics of a new recycled material such as cardboard and pointing out the differences and improvements that this material contributes. With this project we demonstrate a construction system that reduces loads within a building.

Self-production, Optimize, Pollution

Resumen

La autoconstrucción es un escenario que frecuentemente se presenta dentro del ámbito constructivo. El propósito de este proyecto es disminuir el desperdicio de cartón, brindándole un segundo uso y además disminuir el costo de obra principalmente en el ámbito autoconstructivo. A raíz de una investigación exhaustiva acerca de la historia de paneles y su material componente principal que es el poliestireno, se considera el impacto ambiental que el uso del mismo (poliestireno) representa, es por ello que se propone la sustitución del poliestireno, por un material que disminuya o mitigue completamente este problema de contaminación, tomando en cuenta las características de un nuevo material reciclado como lo es el cartón y puntualizando las diferencias y mejoras con las que contribuye este material. Con este proyecto demostramos un sistema constructivo que disminuye las cargas dentro de una edificación.

Autoproducción, Optimizar, Contaminación

Citation: TREJO-TORRES, Zaira Betzabeth, RODRÍGUEZ-URIBE, Juan Carlos and BENITEZ-ALONSO, Margarita. Design and construction of modular panel prototype replacing unicel with the reuse of cardboard. Journal Civil Engineering. 2023. 7-15:22-30.

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Introduction

Nowadays, self-build is a scenario that can be seen almost everywhere you look. In Mexico, self-construction is the main way of producing the city.

This way of producing the city, most of the time, is done with traditional construction methods such as confined masonry walls. Within architecture there are several construction systems, however, they are still not as widely used or even known. Mainly in places where self-building predominates alongside traditional construction systems.

The panel is a construction element that has begun to be implemented as a solution to divide spaces in different buildings, all thanks to its ease of installation and the time required to put it into service, although it is considered that there are some aspects in which the panel could obtain improvements, such as lightness, cost and exchange of unicel for a more ecological material, from a recycled material, easy to handle and that supports self-construction. The degradation time of some materials, such as polystyrene, is too long, according to (UNAM, 2018) it takes between 500 and 800 years to degrade.

As a result of an exhaustive research about the history of the panel and its main component material which is polystyrene, the environmental impact that the use of the same (polystyrene) represents is considered, which is why the substitution of polystyrene by a material that reduces or completely mitigates this pollution problem is proposed, taking into account the characteristics of a new recycled material such as cardboard and pointing out the differences and improvements with which this material contributes, not only to the reduction of pollution produced in construction works, but also to the optimisation of resources and structural improvements such as lightness.

The discovery of expanded polystyrene was made in 1831 with a colourless (transparent) liquid, styrene, which was first obtained from the bark of a tree. Today it is mostly obtained from petroleum.

Polystyrene began to be manufactured in 1930 and towards the end of the 1950s, the German company BASF, on the initiative of Dr. F. Stastny, developed and started production of a new product: expanded polystyrene, under the brand name Styropor. That same year it was used as an insulator in a building within the same BASF plant where the discovery was made. (López & Canepa, 2013).

The material was also considered an excellent product due to its various thermal and mechanical properties. Another point in favour of this product is the ease and simplicity of production (Ruiz et al, 2019).

For some authors, consumerism and overpopulation are the 2 essential causes of the environmental problems we are experiencing today.

With the development of industry, production processes have accelerated, bringing with them two phenomena: the generation of greater volumes of waste and excessive consumption of the goods produced, together with their packaging.

Considering the above, we can say that all citizens are potentially responsible for both the use of resources and the generation of waste.

According to the SEDEMA, packaging has increased the personal production of waste in recent decades, occupying between 30 and 35% of daily waste production. In Mexico, in 2012, approximately 37.5 million tonnes of waste were generated annually; in the last ten years, total MSW generation has increased by 26% (Alma Liriet Álvarez, 2017).

The problem extends to the great waste of paper and cardboard in Mexico, as it mentions (INEGI, 2020), that in 2020 2.8 million tonnes of cardboard were produced where most of it is not recycled and/or ends up in inappropriate places such as natural habitats, sewers, etc.

The cost of the polystyrene w-panel combined with the labour required for its assembly is somewhat high, therefore, in particular cases such as self-construction it is not taken into account.

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The implementation of recycled materials as substitutes for polystyrene is crucial, resulting in a significant decrease in environmental impact. According to the World Bank (2018), Mexico is currently facing a serious environmental problem as it is the third largest rubbish generator in the world and the first among Latin American countries. This project not only seeks to reduce environmental pollution, but also aims to boost the implementation of low-cost panels that are lighter in weight compared to traditional methods such as block walls. It is intended that the scope of the panel is achieved even in low-income areas and can be implemented in self-build projects, due to its simple manufacture and ease of transport and assembly.

The construction sector is a major contributor to economic growth. The investment-driven sector improves the country's long-term competitiveness and affects the quality of life of citizens.

As a result, construction spending worldwide reached more than USD 11 trillion in 2019.

Advanced countries have recently promoted Integrated Modular Construction (MiC) as an effective solution to:

1.- Enable faster construction.

Improve the declining productivity of construction.

2.- Support sustainable development.

In response to the COVID-19 pandemic, the completion of a 1,000-bed MiC-based hospital in Wuhan, China, in less than a month, has got the world, especially sophisticated economies, "talking" about this new technology. (Chan Tsz Wai, 2023).

The five pillars of sustainable architecture

In order to identify the indicators that should regulate the degree of sustainability of a building, one should first start by identifying the general objectives that must be achieved in order to achieve a comprehensively sustainable architecture.

These objectives constitute, therefore, in Figure 1 we can observe the basic pillars on which sustainable architecture should be based (Garrido, 2014).

Pillars of sustainable architecture

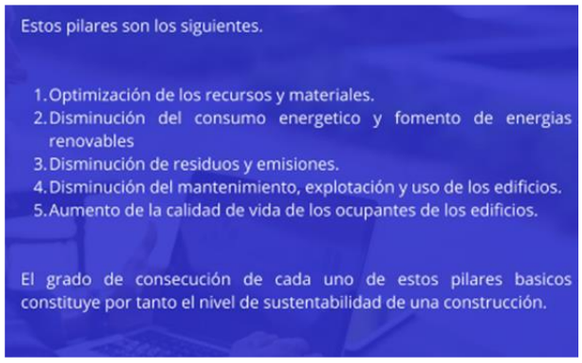

Figure 1 The image shows the five pillars of sustainable architecture by Luis de Garrido
Source: Garrido, 2014

Waste in Mexico

Urban solid waste:

As mentioned, (Ochoa,2010) the management of urban solid waste (USW) in Mexico represents a problem due to several factors, such as lack of basic information, limited economic resources to explore adequate waste treatment systems and technologies and insufficient waste collection, among others, who cites (Comisión Mexicana de Infraestructura Ambiental 2003).

An example is Mexico City, where according to (INEGI, 2020) its population is 9,209,944 inhabitants, where according to a 2004 study the Ministries of Works and Services and Environment announced that the Federal District produces 12 thousand tons of waste per day, an average of 1.5 kilograms per person of waste every 24 hours. (Reyes, 2004).

It indicates that Mexico City recycles barely six percent of the 12,000 tons of waste produced per day. This gives a total of 720 tonnes recovered per day, as shown in Figure 2. (Vázquez, 2011)

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Figure 2 Graph of waste recycling in Mexico City
Source: Vázquez, 2011)

Construction waste:

The continuous growth of cities also brings with it the growth of the construction industry to build the infrastructure that makes it possible for its inhabitants to carry out their activities. This industry generates a large amount of waste, known as construction and demolition waste (CDW), which, if improperly managed, can cause problems that affect the environment, reducing the quality of soil, air and water (Rivera, 2008).

Previous designs

According to Avilés and Nieblas, a structural element such as a wall functions to support load and transmit it to the foundation. According to Avilés and Nieblas, a load-bearing or structural wall is any element that supports compressive, bending, shear, flexural and torsional stresses, derived from gravity loads (dead load and live load), as well as accidental loads (wind and seismic), whether they are made of masonry or any other material. A lightweight wall is any construction element that is composed of materials with physical properties such as low density, reduced thickness, great slenderness, easy handling and installation (Avilés & Nieblas, 2001).

It is a light, insulating and rigid construction element, basically composed of an expanded polystyrene plate reinforced throughout its body by a three-dimensional structure of high-strength steel wire, this reinforcement consists of electro-welded mesh on both sides of the panel joined by a series of perpendicular zig-zag ladders placed at the same spacing, thus forming a three-dimensional structure, as shown in Figure 3 and 4 is a clear example of a structural panel wall. (Avilés & Nieblas, 2001

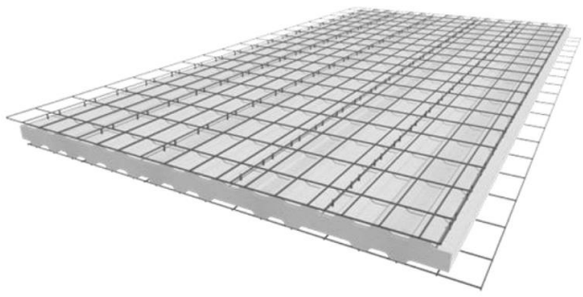

Figure 3 Expanded polystyrene panel wall reinforced with high-strength steel wire tridistructure
Source: Steel Technical Manual), cited by (Avilés & Nieblas, 2001

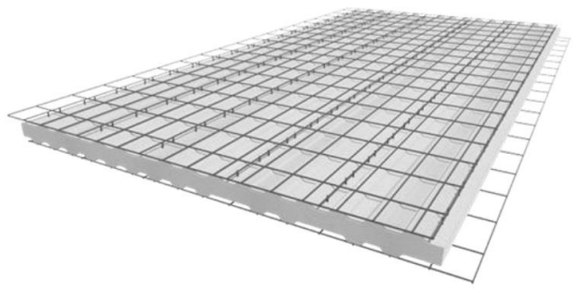

Figure 4 Expanded polystyrene partition panel reinforced with steel wire tridistructure, does not withstand load stresses
Source: Steel technical manual) cited by (Avilés & Nieblas, 2001

Methodology to be developed

Reduction of cardboard waste.

The main material to be used is the leftover cardboard from a packaging company located in Huichapan, Hidalgo. According to (Carlos, 2022) the company consumes approximately 35,000 m2 of cardboard, of which three to five percent of the cardboard becomes waste as shown in Figure 5.

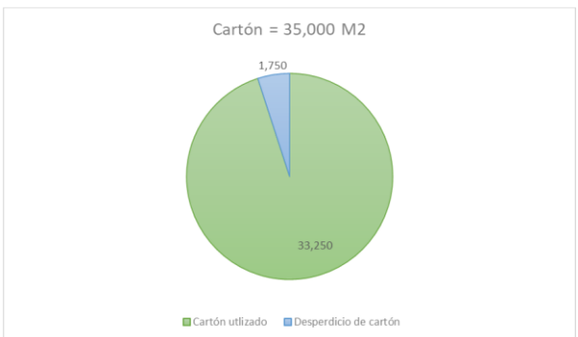

Figure 5 Graph of cardboard waste by packaging company
Source: own authorship, 2022

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It is estimated that making a modular panel measuring one point twenty-two metres wide by two points forty-four metres high would give a total of two points ninety-seven, where for each Modular Panel, zero point sixteen percent of the surplus cardboard would be recycled, as shown in Figure 6, which is produced by the packaging company.

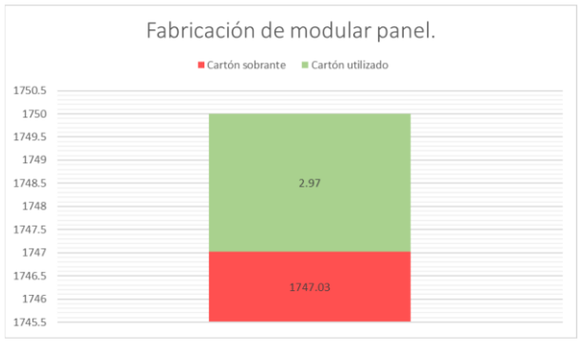

Figure 6 Cardboard recycling graph for each Modular Panel
Source: own authorship, 2022

Design and prototyping integrating plans and 3D modelling.

Design

Taking into consideration that we have all the theoretical foundations, we proceed with pencil and paper to draw some sketches where taking into account the average height of the house in Mexico according to the bibliography of "Barefoot Architect 2020" says that the average height is two point five meters, that is why in the design we contemplate the height of the panel of this measure taking into account that the thickness of the average walls in Mexico is 15 cm in the panel is proposed 10 cm which can be seen in Figure 7.

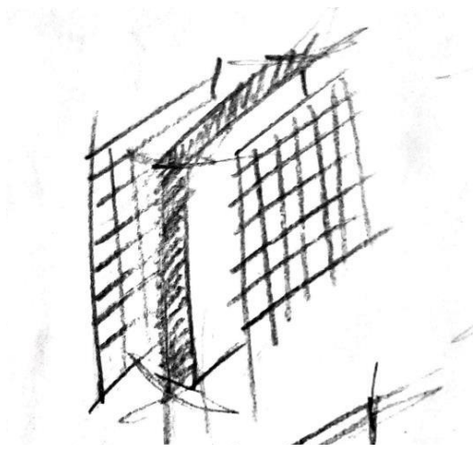

Figure 7 Main idea of the Modular panel
Source: own authorship, 2022

As part of the process, new ideas are given and the design is complemented as shown in Figure 8.

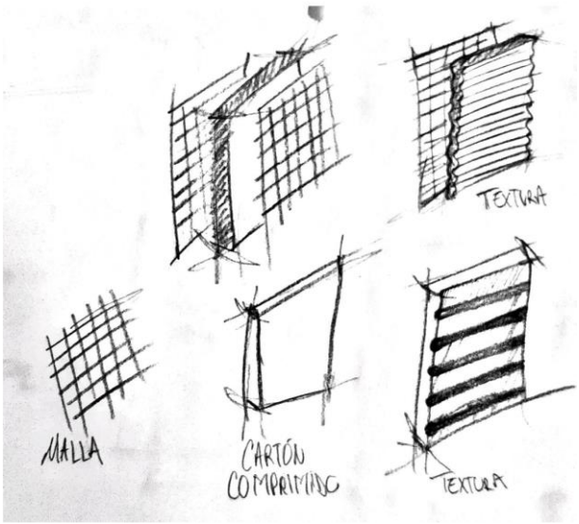

Figure 8 Ideas of the characteristics of the Modular panel, as well as each of its parts, in the design part a texture is implemented in the cardboard
Source: own authorship, 2022

The Modular panel is modelled in a 3D design programme according to the measurements mentioned in Figure 9.

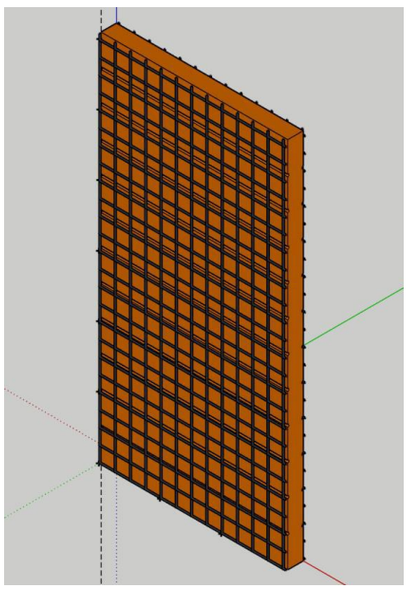

Figure 9 The image above shows the final design from a 3D design program
Source: own authorship, 2022

Subsequently, an isometric view of the development of the Modular Panel is worked on, as shown in Figure 10.

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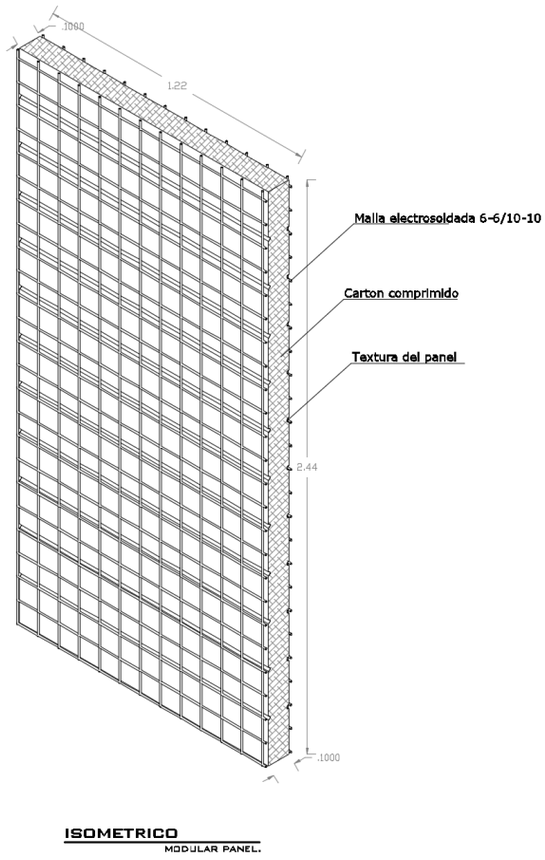

Figure 10 A view of the Modular Panel is shown, as well as measurements and specifications
Source: own authorship, 2022

Results

In the first instance, for the development of the modular panel, the main raw material, which is cardboard, was sought to be recycled or obtained from cardboard remnants that were not useful for any other activity than recycling.

A visit was made to a donor site looking for raw material in good condition from leftovers as shown in Figure 11. The engineer in charge of the site was allowed to explain the process that takes place within the facility. He explained how cardboard waste is generated, as well as the exact quantities that are considered waste as shown in Figure 12.

Figure 11 We visited a cartonera where the die-cutting phase is carried out in search of cardboard waste
Source: own authorship, 2022

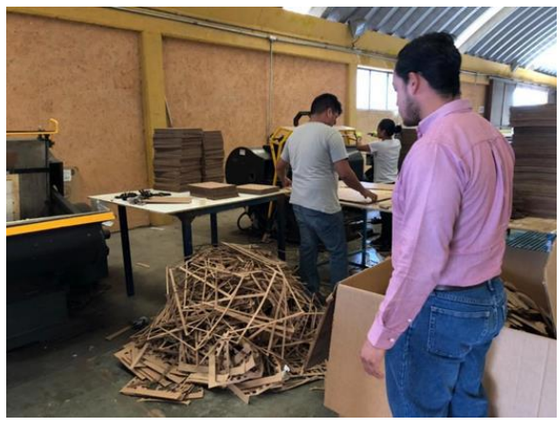

Figure 12 Optimal cardboard waste is obtained for recycling in the Modular Panel prototype
Source: own authorship, 2022

Once the material was obtained, it was concluded that although the waste was smaller than a cardboard plate, the waste still had a considerable size to be able to handle the material, which is why a further process was carried out to obtain smaller pieces of cardboard as shown in Figure 13.

Figure 13 Small pieces of cardboard were made from the strips of cardboard produced by die-cutting, making sure that they were no larger than 5 cm
Source: own authorship, 2022

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Now, having the cardboard ready for mixing, the next step is to make a mould that provides the desired texture for the panel, as shown in Figure 14.

Figure 14 Construction of the mould, the texture seeks a good performance in the face of the plaster
Source: own authorship, 2022

Once the mould is made, the mixing of the ground cardboard and Resistol 950 is started, see Figure 15.

Figure 15 Mixing of cardboard with Resistol 950. The mixture is mixed little by little to make it more homogeneous
Source: author's own work, 2022

The mixture made by shredding the cardboard and Resistol is then placed inside the mould, which is left to dry for three days as shown in Figure 15.

Figure 16 Placing the mixture inside the mould
Source: own authorship, 2022

Once the drying process is complete, the mould is removed as shown in Figure 16.

Figure 17 With the help of a spoon, the mould can be removed from the cardboard plate
Source: own authorship, 2022

Cost analysis

As part of the methodology, a cost analysis was carried out using the programme (Microsoft Excel, 2019) where the result was very positive compared to traditional systems (masonry), as shown in Figure 17. Since the saving is quite a lot compared to the Modular panel, it is therefore advisable to use it in self-construction in Mexico, for its great importance on the reuse of cardboard, as well as giving a new use to cardboard, which is why with this analysis we could realize that the cost decreased by 32% having as cost in the traditional system (masonry) per module of three meters by two points five meters in height a cost of $14,195. In comparison with the Modular Panel with a cost per module of $9,630.

ISSN: 2523-2428

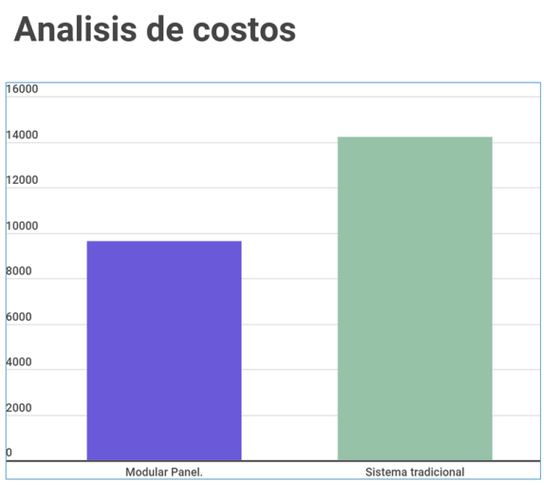

Figure 18 The graph shows the costs of the two construction systems
Source: own authorship, 2022

Prototype construction

As indicated in the methodology, the construction of the designed panel is carried out. This panel complies with expected characteristics such as lightness, lower cost than other systems and also its construction process promotes the reuse of cardboard. The prototype proposes a way of building that is friendly to the natural environment, as shown in Figure 18.

Figure 19 The different layers of the panel can be seen. The first layer or core is compressed cardboard, the second layer is mesh and finally there is the gypsum sheathing
Source, own authorship, 2022

The Modular Panel is designed so that the panels are joined together by means of the mesh, i.e. the mesh of one panel can be joined to the mesh of another panel, as shown in Figure 19.

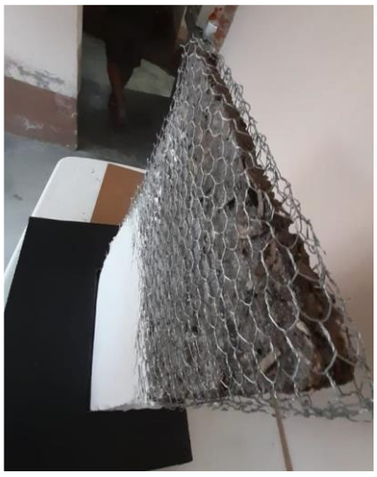

Figure 20 The figure shows the mesh that not only acts structurally, but also as a connection between panels
Source, own authorship, 2022

Acknowledgements

We thank the Tecnológico Nacional de México, and the Instituto Tecnológico Superior de Huichapan, for the availability for the use of the laboratory and facilities, as well as the active participation of the 7th semester students; Florencio Camacho Pérez, Luis Antonio Pintor, Rogelio Greg Ventura, Pedro López Anaya.

Funding

The project was not financed during its construction process.

Conclusions

Once the previous studies of the present project have been carried out, we have the necessary and sufficient information that allows us to reach the following conclusion:

Derived from this research, the development of a Modular Panel is obtained, which favours in the process of self-construction and allows the development of the same in a minimum time derived from the fact that it is considered a non-structural panel, taking the function of dividing panel.

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We were able to observe that the reuse of cardboard is of utmost importance since there are companies that are dedicated to the development of cardboard-based packaging and that the waste they generate is practically discarded.

We also consider that the thermal conditions offered by the Modular Panel are favourable for climates with low temperatures.

We also determined the cost, which is reduced by 32% compared to existing traditional systems.

Finally, it can be said that this Panel favours the development towards a sustainable and sustainable architecture.

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ISSN: 2523-2428

Article **Journal Civil Engineering**
December 2023, Vol.7 No.18 31-39

Hydraulic concrete design with addition of natural ocoxal fiber (pine needle)

Diseño de concreto hidráulico con adición de fibra natural de ocoxal (acícula de pino)

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DOI: 10.35429/JCE.2023.18.7.31.39 Received July 25, 2023; Accepted December 30, 2023

Abstract

Conventional concrete has relatively low tensile capacity and ductility and is therefore susceptible to cracking. Determine the result of the addition of natural ocoxal fiber (pine needle) in hydraulic concrete to the axial compressive stress. The general method was scientific, the type of research was applied, the level was explanatory and the design was quasi-experimental. The population corresponded to three specimens of concrete cylinders with 10%, 15% and 20% addition of natural ocoxal fibers by volume. The axial compression strength test was only carried out 28 days after setting. Cylinder #1 containing 10% volume of ocoxal was the one that achieved the lowest result with an f'c= 101.50 kgf/cm^2, cylinder #2 with 15% volume of ocoxal achieved an f'c= 140.43 kgf /cm^2 and cylinder #3 with 20% volume of ocoxal achieved the highest f'c= 150.54 kgf/cm^2, the average of the three cylinders was f'c=130.8 kgf/cm^2.

Pine needle (ocoxal), Compressive stress, Concrete

Resumen

El hormigón convencional tiene una capacidad de tracción y ductilidad relativamente bajas y, por tanto, es susceptible a agrietarse. Determinar el resultado de la adición de fibra natural de ocoxal (acícula de pino) en el concreto hidráulico al esfuerzo de compresión axial. El método general fue el científico, el tipo de investigación fue aplicada, el nivel fue explicativo y el diseño fue cuasi experimental. La población correspondió a tres especímenes de cilindros de concreto con 10%, 15% y 20% de adición de fibras naturales de ocoxal en volumen. La prueba de resistencia a la compresión axial sólo se realizó a los 28 días de fraguado. El cilindro #1 que contiene el 10 % de volumen de ocoxal fue el que menor resultado alcanzó con un f´c= 101.50 kgf/cm^2, el cilindro #2 con un 15% de volumen de ocoxal logró un f´c= 140.43 kgf/cm^2 y el cilindro #3 con un 20% de volumen de ocoxal logró el mayor f´c= 150.54 kgf/cm^2, en promedio de los tres cilindros fue de f´c=130.8 kgf/cm^2.

Acícula de pino (ocoxal), Esfuerzo compresión, Concreto

Citation: CASTELÁN-URQUIZA, Demetrio. Hydraulic concrete design with addition of natural ocoxal fiber (pine needle). Journal Civil Engineering. 2023. 7-15:31-39.

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† Researcher contributing as first author.

Introduction

The durability of a concrete infrastructure is defined by its ability to maintain reliable levels of serviceability and structural integrity under potentially harsh environmental exposure without the need for significant repair intervention throughout its design life.

Conventional concrete has relatively low tensile capacity and ductility and is therefore susceptible to cracking. Cracks are considered to be ways for harmful gases, liquids and solutes to enter the concrete, causing the early appearance of deterioration processes in the concrete or reinforcing steel (Paul et al., 2020).

Chen et al., (2023), conducted a literature review of natural fibers and their use in concrete, reaching the conclusion that to reduce the carbon footprint of traditional concrete materials, concrete with natural fibers is vital. . The findings indicate that natural fiber reduces the cracking rate of concrete, increasing tensile strength. Although fibers improve the distribution of stresses within the concrete, increasing its stability, reducing compressive strength, natural fiber concretes present considerable environmental benefits; The studies reviewed indicate effective economic and social sustainability, respectively.

Abdalla et al., (2023), states in their research that the use of fibers has increased enormously to create significantly robust structures. For sustainable and zero-waste development, manufactured fibers can be replaced with natural fibers without compromising requirements.

Hamada et al., (2023), comment that plant fibers play a crucial role in reinforcing the mechanical behavior of cement concrete, especially tensile and flexural strengths. The important disadvantages of natural fibers are the relatively high moisture absorption and hydrophilic behavior, which results in reduced bonding between the concrete matrix and the fibers and therefore affects the overall performance of the concrete material.

Ahmad et al., (2022), concluded in their research that jute fibers improved the aspect of strength and durability, but decreased the fluidity of concrete in a similar way to synthetic fibers. However, little research is available on the durability of jute fiber reinforced concrete. Furthermore, the optimal percentage of jute fiber in concrete is essential as the higher dosage negatively affects the strength and durability characteristics due to lack of fluidity.

Veigas et al., (2022), explored the use of sisal fiber. To address the potential degradability of this natural fiber, two different coatings were examined, i.e., polyester resin and bio-based shellac. To this end, several mixtures made with a variety of sisal fiber dosages, including coated and uncoated sisal fibers, were investigated. The study explored the mechanical properties of the developed mixtures through compression, tensile and flexural strength tests. From the results obtained, notable improvements were observed in the main resistance properties, compared to mixtures that did not contain fibers.

Boumaaza et al., (2022), comments that the results indicate that the treatment of the fibers improves adhesion in the mortar matrix systems of composite materials obtained. It increases its water absorption capacity and decreases its thermal conductivity, thus contributing to heat absorption and, above all, its durability.

Recently, the addition of various natural fibers to high-strength concrete has sparked great interest in the field of construction materials. This is because natural fibers are much cheaper and available locally, compared to synthetic fibers (Shah et al., 2022).

Jamshaid et al., (2022), states that the water absorption capacity of concrete reinforced with natural cellulosic fibers decreased substantially; however, it increased with the percentage of fiber loading. Natural fiber reinforced concrete can be used commercially for interior or exterior pavements and floor slabs as a sustainable building material for the future.

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Kurpińska et al., (2022), reviewed the properties of cement composites reinforced with short fibers, investigated the effect of natural fibers: cotton, sisal, jute, ramie, bamboo and synthetic fibers: polymer and polypropylene. It was observed that the fibers change the consistency of the mixture. In flexural strength testing of composites, a change in strength was noted. It had a positive effect on the compressive strength, in addition, the chemical composition, diameter and total length of the fibers of the element have an impact on the shrinkage of the composite. Fiber-containing composites showed higher water absorption compared to fiber-free samples. The exception is ramie fibers, which reduce water absorption.

Organic fibers such as coconut fiber, palm, kenaf, jute, sisal, banana, pine, sugar cane and bamboo, were studied by several researchers as construction materials that can be found in pulp cement, mortar and concrete. Results with low fiber were observed to be the most promising (Shadheer Ahamed et al., 2021).

Delgado Zambrano & Delgado Benavides, (2023), state that the use of natural fibers (banana, pineapple, coconut, sawdust and fique) as reinforcement in construction materials, specifically as a replacement for synthetic fibers in reinforced concrete, has been increasing in recent years due to its mechanical, economic and environmental benefits, opening a new field of research in the industry. In addition to these benefits, these fibers are biodegradable, abundant and can be classified as organic waste of industrial origin.

Awwad et al., (2011) indicated that the use of natural fibers (fibers from industrial hemp, palm and banana leaves) resulted in a reduction in the amount of coarse aggregate without affecting the flexural performance of the concrete. However, no clear trend was determined in the compressive strength test results of the cubes.

Steel, glass or polymer fibers are viable but expensive alternatives. Natural fibers may be a real possibility for developing countries, as they are available in large quantities and represent a continuous renewable source. The fiber is mainly affected by the alkalinity of the concrete matrix.

The durability of the composite will then depend on the protection that the fiber has and the impermeability characteristics of the matrix (Juárez Alvarado et al., 2004).

Chen, C., & Chen, R. (2023), investigated the use of magnesium oxide (MgO) in hydraulic concrete in the following projects in China: Baishan Hydropower Station unexpectedly discovered the beneficial effects of MgO; Dongfeng Hydropower Station actively used MgO as a blowing agent for the first time in the main project; Changshaba Hydropower Station used the blowing agent MgO in a full-arch dam for the first time; Huangjiazhai Hydropower Station exceeded 6% MgO content for the first time in concrete in normal state; and the Dahe deposit exceeded 6% MgO content in roller-compacted concrete for the first time.

Tian et al.,(2023), analyzed as an intrinsically self-sensing material, carbon fiber concrete has promising structural health monitoring applications. Investigating the long-term stability of carbon fiber concrete in terms of resistivity changes under the influence of factors such as aging effects and environmental conditions may help evaluate its viability for long-term monitoring applications.

Li et al., (2023), investigated the aggregate grading design of asphalt concrete. As fine aggregates and coarse aggregates perform different functions in an asphalt mixture, coarse aggregates (2.36–19 mm) and fine aggregates (0.075–2.36 mm) were considered differently for grading design. According to the interference theory, the optimal skeleton gradation of coarse aggregates was determined by step-by-step filling vibration compaction. For the gradation of fine aggregates, a mathematical model was obtained based on the fractal theory of gradation and the Dinger-Funk equation.

Emamjomeha et al., (2023), in their research the study was designed and implemented to evaluate the effects of silica fume, zeolite and blast furnace slag (BFS) on engineering cementitious composites and to compare the mechanical properties and the durability of polyvinyl alcohol-ECC (PVA-ECC) and polypropylene

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Huaquisto et al., (2023), in their research evaluated the physical-mechanical behavior of hydraulic concrete with additions of fibers from PET plastic bottles and natural river aggregates. The concrete was evaluated in the fresh state using Slump and in the hardened state using density and compressive and flexural resistance, for which cylindrical and prismatic specimens were prepared with PET fibers in proportions of 2%, 4%, 6%. and 8% by weight of cement plus the standard concrete designed for 21 MPa. It was found that the slump and density of concrete decreased with the addition of PET fibers.

Theoretical framework

Cemex-Tolteca Extra brand CPC-30R Portland gray cement

Figure 1 shows CPC 30R Extra Cement is specially formulated to reduce the appearance of plastic shrinkage cracks in concrete exposed to extreme environmental conditions, improve the consistency of the mixture, produce a mixture that is easier to handle and avoid the process curing, a unique product on the market. CPC 30R Cement meets the specifications of the Mexican standard NMX-C-414-ONNCCE.

Figure 1 Bulk of extra gray Portland type cement, CPC-30R, CEMEX-Tolteca Brand
Source: Own elaboration

Applications

CPC 30R Extra Cement is special for exposed surfaces such as pavements and slabs, it is recommended for structural uses of reinforced or simple concrete (such as floors, castles, dalas, walls, footings, girders, columns) and/or masonry (branching, similar , repairs, pasting). It is compatible with conventional materials used in construction, achieving excellent results.

Characteristics

Mechanical specifications: Compressive strength at 28 days, test method NMX-C-061 = 30 N/mm2, minimum expected value.

General objective

Determine the result of the addition of natural ocoxal fiber (pine needle) in hydraulic concrete to the axial compressive stress.

General hypothesis

The addition of natural ocoxal fiber (pine needle) will increase the values of the mechanical properties to the axial compressive stress of the hydraulic concrete.

Materials

The materials that were used for the construction of the prototypes were from the region of the Municipality of Valle de Bravo, State of Mexico.

- Cemex-Tolteca Extra brand CPC-30R Portland-type gray cement.
- Grave ¾´´.
- Sand.
- Water.
- Pine needle (ocoxal).
- Nopal mucilage.

Tools

- Weighing machine
- Shovel
- Trowel
- Vernier
- 19 liter plastic containers.
- Metal cylinders.

Machinery.

- Universal Machine Controls brand.

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Methodology to be developed

The general method was scientific, the type of research was applied, the level was explanatory and the design was quasi-experimental. The population corresponded to three specimens of concrete cylinders with 10%, 15% and 20% addition of natural ocoxal fibers. The axial compression strength test was only carried out 28 days after setting.

Regarding the treatment of the ocoxal fiber, the mucilage of nopal (nopal slime) was taken as a moisture waterproofing agent, cutting two nopales into small pieces, letting it rest in a 5 liter container with water. for 24 hours and extracting the nopal mucilage, straining it, to submerge the ocoxal just before mixing with the other aggregates.

The proposed dosage of the compressive strength of the hydraulic concrete was f´c= 250 kg/cm2, this dosage was based on self-construction construction procedures, which is indicated in the volume of 19 liter plastic containers, in the packages of extra gray portland type cement, CPC-30R, CEMEX-Tolteca brand.

Results

Design of the hydraulic concrete mix with the addition of natural ocoxal fiber.

For the preparation of concrete, the proportions of the different materials recommended in the bulk of gray cement, to obtain the resistance to axial compression stress f'c = 250 kgf/cm2, are shown in Table 1, the quantity of materials is indicated. in 19 liter containers. in proportion to a lump of cement.

Application (uses)	Cement (50 kg package)	Grave ¾" l (19 liter cans)	Sand (19 liter cans)	Water (19 liter cans)	Resistance f´c (kg/cm²)
Walls and floors	1	8.5	8.0	3.0	100
Castles and dalas	1	6.5	5.5	2.5	150
Slabs and footings	1	6.0	4.0	2.0	200
Columns and special slabs	**1**	**5.0**	**3.5**	**1.5**	**250**
High resistance concrete	1	4.5	2.5	1.5	300

Table 1 Material proportions
Source: Own elaboration

Table 2 shows the dosages of the materials, the quantities in liters of cement, gravel, sand and water do not change, for the three cylinder specimens what varies is the percentage of natural ocoxal fiber.

#Cylinder	Cement (lts.)	Grave ¾" (lts.)	Sand (lts.)	Water (lts.)	Ocoxal (lts.) (%de 19 lts.)
1	3.1654	7.9154	5.5404	2.356	1.90 (10%)
2	3.1654	7.9154	5.5404	2.356	2.85 (15%)
3	3.1654	7.9154	5.5404	2.356	3.80 (20%)

Table 2 Proportions of materials to be used per cylinder specimen
Source: Own elaboration

Development of the preparation of the concrete mixture with the addition of natural ocoxal fibers

The natural pine needle fiber (ocoxal) was collected Figure 2 shows the drying and its composition can be seen.

Figure 2 Drying of natural ocoxal fiber
Source: Own elaboration

In Figure 3, the natural fiber was immersed to give it a waterproofing treatment with cactus mucilage in a container.

Figure 3 Washing of the natural fiber of (ocoxal)
Source: Own elaboration

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A hard, clean surface was used to mix, moistening it with water. Figure 4 shows the mixing of the materials.

Figure 4 Mixing of concrete aggregates
Source: Own elaboration

Figure 5 shows when the mixture of cement with sand, gravel and water free of impurities was made to make the hydraulic concrete cylinders.

Figure 5 Preparation of the concrete mix
Source: Own elaboration

Figure 6 shows the metal cylinders filled with fresh concrete added with natural ocoxal fibers. The mixture was vibrated to dislodge the air trapped in the concrete in the metal molds and after 24 hours. They were cured by immersing them in water.

Figure 6 Preparation of concrete cylinders
Source: Own elaboration

Axial compression test results

After making the cylinders and curing them for 28 days, the axial compression test was carried out in the universal machine, on the three specimens of the hydraulic concrete cylinders. Table 3 shows the results of the compressive stress, having As a result, cylinder #1 containing 10% volume of ocoxal was the one that achieved the lowest result with an f'c= 101.50 kgf/cm^2, cylinder #2 with 15% volume of ocoxal achieved an f'c= 140.43 kgf/cm^2 and cylinder #3 with 20% volume of ocoxal achieved the highest f'c= 150.54 kgf/cm^2, the average of the three cylinders was f'c=130.8 kgf/cm^2.

#Cylinder	Axial load (kgf)	Cylinder area (cm^2)	Compressive stress f´c (kgf/cm^2)
1	17,937.00	176.71	101.50
2	24,816.50	176.71	140.43
3	26,601.73	176.71	150.54
Average	23,118.41	176.71	130.80

Table 3 Axial compression test results
Source: Own elaboration

In graph 1 it can be inferred that the greater the volume in liters. of the percentage of 10%, 15% and 20% of natural ocoxal fibers, the highest result obtained was 20% with a resistance to axial compression stress of f'c=150.54 kgf/cm^2, compared to the f'c design, 100 kgf/cm^2 were missing to reach the design resistance, which was f´c= 250 kgf/cm^2.

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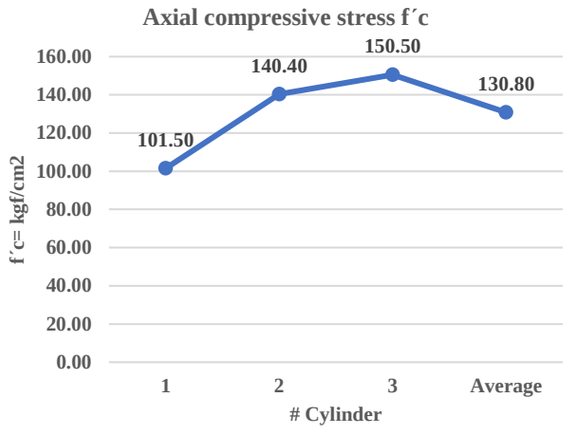

Graphic 1 Axial compression stress of the three cylinders
Source: Own elaboration

Conclusions

Natural fibers are easily accessible and can be biodegraded, ocoxal (pine needle) is found in large quantities and its use is only to make regional crafts, in the municipality of Valle de Bravo, State of Mexico, Mexico.

By adding the natural fiber treated with cactus mucilage to waterproof it and not degrade it due to the cement matrix present in the concrete, it was possible to achieve axial compression stress values below the design resistance, which was f'c=250. kgf/cm^2, achieving a maximum value of 150.54 Kgf/cm^2, which contains 20% of 19 liters of natural ocoxal fiber.

The results indicate that the higher the percentage of natural ocoxal fiber in the three specimens, the greater the resistance to axial compression stress was achieved. This is due to the design of the empirical concrete, since this is what the table found in the packages indicates. of cement and is what supports the empirical design of hydraulic concrete, taking as reference the resistance to axial compression stress f'c=kgf/cm^2 for the different uses and applications of hydraulic concrete.

This type of cement is used in self-construction and the dosage of concrete is in volume of 19 liter plastic containers. which implies low quality control in the production of hydraulic concrete, compared to concrete made in a plant.

The average resistance of the three specimens is 130.80 kgf/cm^2, which is greater than 50% of the design resistance f'c= 250 kgf/cm^2, so it is inferred that by adding a high percentage of fibers Natural ocoxal increases the resistance of the concrete to the axial compression stress of hydraulic concrete, but does not reach the expected resistance.

The use of hydraulic concrete is proposed for columns and special slabs with a f´c= 250 kgf/cm^2, due to the results obtained its use could be applied to non-structural floor or pavement pavements, castles, dalas and poor concretes (low endurance). The research focused on the design of hydraulic concrete with the addition of natural ocoxal fibers to know the resistance to axial compression stress, which implies in future research to calculate the bending stress of hydraulic concrete.

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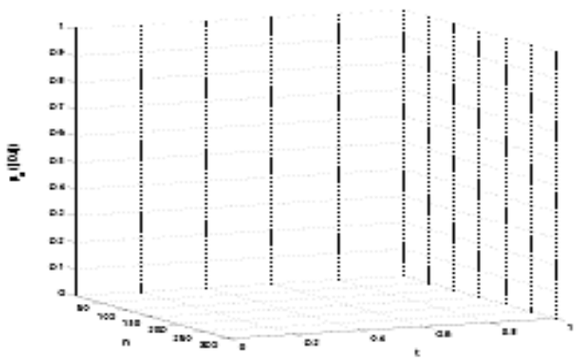

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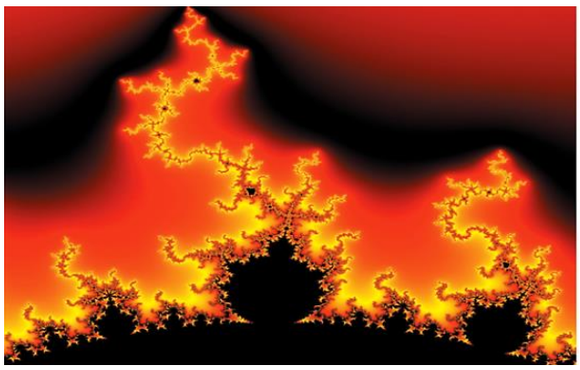

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Journal Civil Engineering

2523 2428
ISSN 2523-2428