

ISSN 2523-2428

Volume 5, Issue 13 — January — June — 2021

Journal Civil Engineering

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Journal Civil Engineering, Volume 5, Issue 13, January to June, 2021, is a magazine published biannually by ECORFAN-Peru. La Raza Av. 1047 No.-Santa Ana, Cusco Peru. Postcode: 11500. WEB: www.ecorfan.org/republicoferu, 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 30 June 2021.

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Journal Civil Engineering

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Support the international scientific community in its written production Science, Technology and Innovation in the Field of Engineering and Technology, in Subdisciplines Bridge construction, development of environmental engineering, management in housing construction, hydraulic infrastructure, soil mechanics, sanitary engineering, road infrastructure.

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The works must be unpublished and refer to topics of Bridge construction, development of environmental engineering, management in housing construction, hydraulic infrastructure, soil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, *Asphalt mixes with recycled construction and demolition materials for pavement repair*, by TÓRRES, Rodrigo, FLORES, Paola, FLORES, Mariana, FLORES, Víctor and MAIRON, Kevin, seconded to the Universidad Mayor, Real y Pontificia de San Francisco Xavier de Chuquisaca, as next article we present, *Construction elements for ecological houses*, by FLORES, Víctor, ROJAS, Jesús, TORRES, Rodrigo, VALLEJOS, Rolando, FLOWERS, Paola and FLORES, Mariana, , seconded to the Universidad Mayor, Real y Pontificia de San Francisco Xavier de Chuquisaca, as next article we present, *Recovery of saline soils with the incorporation of calcium sulphate hemihydrate ($Ca(SO_4) \frac{1}{2} H_2O$) in the community of Yotala*, by FLORES, Eddy, FLORES, Juan and TÓRREZ, Jorge, with secondment at the Universidad Mayor, Real y Pontificia de San Francisco Xavier de Chuquisaca, finally, we present, *Stress concentration in a plate with two centered holes subjected to axial loading*, by ORTEGA, Francisco, PALACIOS, Francisco, GARCIA, Diego and GARCIA, José, seconded to the Instituto Tecnológico Superior de Irapuato.

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Asphalt mixes with recycled construction and demolition materials for pavement repair

Mezclas asfálticas con materiales reciclados de construcción y demolición para la reparación de pavimentos

TÓRRES, Rodrigo†, FLORES, Paola, FLORES, Mariana, FLORES, Víctor and MAIRON, Kevin

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DOI: 10.35429/JCE.2021.13.5.1.6

Received 10 January, 2021; Accepted 30 June, 2021

Abstract

The objective of this research was to demonstrate that it is possible to develop an asphalt mix material for construction and demolition, which could be used in pavement repair or patching. The study was mainly to collect the recyclable waste in stone aggregates chosen by crushing using to prepare an asphalt mixture, which was subjected to several laboratory and field tests to determine its mechanical behavior. The results were within the accepted norm ranges. Lastly, an analysis of the costs per cubic meter of recycled shows revealing a 14% savings compared to a traditional direct cost mix.

Asphalt, Durability, Mix, Recycling, Waste

Resumen

El objetivo de esta investigación fue demostrar que es posible desarrollar un material de mezcla asfáltica para la construcción y la demolición, que podría utilizarse en la reparación o el parcheo de pavimentos. El estudio consistió principalmente en recoger los residuos reciclables en agregados pétreos elegidos por trituración utilizando para preparar una mezcla asfáltica, que fue sometida a varias pruebas de laboratorio y de campo para determinar su comportamiento mecánico. Los resultados estuvieron dentro de los rangos normativos aceptados. Por último, un análisis de los costes por metro cúbico de reciclado revela un ahorro del 14% en comparación con una mezcla tradicional de coste directo.

Asfalto, Durabilidad, Mezcla, Reciclaje, Residuos

Citation: TÓRRES, Rodrigo, FLORES, Paola, FLORES, Mariana, FLORES, Víctor and MAIRON, Kevin. Asphalt mixes with recycled construction and demolition materials for pavement repair. Journal Civil Engineering. 2021. 5-13:1-6.

† Researcher contributing as first author.

Introduction

The repair of roads in our environment is carried out based on flexible pavements with asphalt emulsions and aggregates derived from natural rock extracted from nearby quarries, the pavements are subjected to environmental agents such as temperature, humidity and precipitation that reduce their durability which extends the frequency of repairs that must be carried out to maintain operating standards.

The use of recycled materials can contribute significantly to the reduction of the environmental impact in this type of works, it avoids the depletion of raw materials since it reduces the extraction activity of primary materials by substituting a percentage of the borrowed material that usually comes from quarries, and reduces the volume of waste occupied in landfills, consequently, the advance in this technique contributes significantly to reducing the environmental impact.

In the present investigation, recycled construction materials were used to design a mixture, trying to achieve an exact determination of the properties of the asphalt cement in order to characterize the material and thus be able to predict the response and the possible failures that may occur.

It was shown that recycled aggregates have their own physical properties and characteristics that improve performance, ensure results and prolong the useful life of mineral materials in public works.

For the use of this material in the repair of pavements for highways and urban roads to be possible, it is necessary to use chemical additives that, when added to the asphalt, increase its resistance and delay its aging.

Background

Research on the use of recycled aggregates in construction has focused more on lines of bituminous mixtures and concrete made from recycled material.

In Germany, 60 million tons of recycled aggregates are currently produced, of which more than 40 million are used for the maintenance and construction of bases and sub-bases for highways and urban roads.

Starting in 1993, the RG Min-STB 93 Directive facilitated the growth of the recycling sector in Germany and made it possible to demonstrate that recycled aggregates are very competitive in the markets for granular materials intended for the construction of foundations and sub-bases. roads.

A pioneering example in Spain in terms of on-site recycling is the plant set up by Dragados in Barajas, which began operating in February 2000. The plant has made it possible to take advantage of stone materials from the demolition of concrete and asphalt slabs at the airport. This experience is not applicable to works in which the recycled material must come from a construction and demolition waste treatment plant, in which the waste can have different origins, and strict controls must be applied to the quality of the resulting recycled material.

Other experiences in the use of recycled aggregates can be found in the construction of the Green Cycling Ring of the Community of Madrid and in the Green Corridor of Parque de las Cañadas (Cádiz).

Additionally, it has been found that the rheological characteristics of the asphalt binder in the mixture also have a significant influence on the visco-plastic behavior of these materials. In the mechanistic design of pavements, the vertical forces that the subgrade layer supports are controlled, in order to avoid the formation of traces on the surface. However, no design methodology controls the permanent deformations produced by the visco-plastic behavior of asphalt mixtures.

Problem statement

Construction waste is a pollutant that infertilizes the soil, constituting a problem for the environment, in addition to the lack of new alternatives for its recycling, such as its use in the repair of asphalt pavements.

Justification

One of the main problems in the world is environmental pollution. The need to recycle construction waste does not only concern the largest countries or the most industrialized communities, but also a global demand.

Many countries, ranging from the most developed to developing countries like ours, could experience the saving of natural resources and preservation of the environment using these recycling techniques. Therefore, it is necessary to inculcate this recycling culture in addition to that of preserving the environment, a culture that could have economic advantages that would favor the development of our peoples, since there are no initiatives that allow short-term solutions, such as the case of asphalt mixtures with construction and demolition materials.

Construction waste is a pollutant that infertilizes the soil, constituting a problem for the environment, in addition to the lack of new alternatives for its recycling. Hence the importance of incorporating recycling techniques that allow us to reduce environmental pollution due to construction waste and that will reduce the amount of bench materials used, in addition to lowering costs and obtaining the resistance required by standard in the construction of pavements.

Objectives

General Objective

Obtain an asphalt mixture with recycled construction and demolition waste for its application in the repair or patching of pavements, thus contributing to the non-contamination of soils and the preservation of the environment.

Recheck bibliographic information

Determine the characteristics of recycled materials and their suitability for use in asphalt mixtures.

Determine and evaluate resistance through tests

Check the evolution of the behaviour of each mixture made, comparing it with that of traditional asphalt. Contribute to the reduction of contamination by construction waste.

Prepare the asphalt mixture with construction and demolition waste for its subsequent comparison and evaluation of behaviour with traditional asphalt.

Disseminate the results, through scientific fairs, triptychs, diptychs, etc.

Hypothesis

With the addition of recycled construction and demolition materials in asphalt mixtures, it is a matter of obtaining a material with better resistance, low cost and characteristics similar to conventional ones, to be used in the repair or patching of pavements. In this way we contribute to recycling and non-contamination by this type of waste.

Materials and method

Materials

The materials used are:

- Asphalt Emulsion.
- Crushed concrete.
- The Crushed rill.
- Sieve.
- Foundry vessels.
- mixing paddle.
- Burner.
- Fuel (LPG).

Other materials

- Kerosene (for curing).
- Chemical additives.

Methodology

The study will proceed as follows.

It will be developed in 5 stages:

In the first stage, the collection of the materials was carried out, where mainly concrete rubble, blocks, and bricks were obtained, once the samples were collected, they were crushed, this process was carried out for each material to obtain the aggregates separately. Next, they were mixed proportionally, homogenizing the samples and drying them. Finally, a representative sample was taken by quartering and the characterization of the petrous material was carried out.

In the second stage, various tests were carried out to obtain the physical characteristics of the aggregates.

The tests carried out were:

Loose dry volumetric weight to obtain the weight of solid particles per unit volume, expressed in kg per cubic meter.

Particle size analysis to classify the material particles by size, passing it through a succession of meshes, obtaining the weight of the particles retained as a percentage of the total sample.

Relative density, obtained as the ratio of the density to the absolute, including its voids

Absorption percentage, to determine the amount of water absorbed by the stone material previously saturated with water at a temperature between 15° and 25°C for 24 hours.

Equivalent of sand, whose purpose was to determine in the fraction that passes the mesh number 4.75 under established test conditions, the volumetric proportion of particles of size greater than that of clay, with respect to the volume of fine particles of size like that of clay.

In the third stage, the mixture was made with the different types of rubble.

Subsequently, the asphalt mixture was subjected to an unconfined compression test to assess the maximum fatigue that a specimen made with standardized test dimensions and conditions would withstand.

In the fourth stage, the specimens were classified according to the granulometry used. As a fifth and last stage, a comparative analysis of costs was carried out at unit price of both mixtures, the traditional one and those obtained from materials recirculates considering the concepts of removal, loading, and unloading, supplies, hauling, accommodation, compaction of materials, etc.

The direct cost was integrated into items, namely: a) materials, b) labor, c) equipment and minor tools, and d) basics of the asphalt mixture.

Results and Discussion

Strength and stability tests (casting)

2 ½ in. cylindrical test pieces. tall and 4 in. in diameter to determine the optimum content of asphalt cement. Two types of asphalt cement were used, one conventional and the one modified with 5% polyethylene.

And using the optimal content of asphalt cement, which for both cases was 8%, and two test conditions were carried out, dry and under humid conditions. Additionally, a second experiment was carried out within the GA open granulometry to know the behaviour of a mixture rich in asphalt, which would provide the pavement with much greater durability.

In all cases, the specimens were tested in dry and under humid conditions, to simulate the possible damage that water can cause in the mixtures, these conditions were given by means of an immersion treatment in water for 4 hours at a temperature of 60°C, after this period the specimens were allowed to return to room temperature and then tested in the same way as the dry specimens.

These tests were carried out to determine if the aggregates with which the design was made meet the specifications required for the conformation of the asphalt mixture under study. A total of 16 specimens were analysed, 10 in the resistance test of the mixture (2 for each sample) and 6 in the loss of stability by immersion (2 for each one).

The table shows how the studies were classified.

Pruebas	Muestras de material seleccionado	
	Reciclada	Tradicional
Peso volumétrico seco suelto kg/m ³	1183	1233
Análisis granulométrico, % p.e. para		
Malla No. 4	42	42
Malla No. 40	12	18
Malla No. 200	8	10
Densidad, g/cm ³	2.14	2.06
Absorción, %	11.3	11.8
Equivalente de arena, %	33	43

Table 1 Studies made to the add oil

In the table above, the volumetric weight and granulometry data of the recycled samples were slightly lower than the traditional ones, but higher in all the other tests, without this meaning that it was not within the ranges accepted by the official regulations. It is noted that the increase in average absorption can be attributed to the high void ratio implicit in the material obtained from the recycled concrete blocks. Likewise, the 40% limit of the specifications is evident by virtue of the heterogeneity of the components used. In the same way, the tests carried out on the asphalt mixture that can be seen in table 2, yielded acceptable results in the tests carried out. However, sample A was discarded because it did not homogeneously cover the petrous material under study, consequently choosing sample b for the development of the mixtures to be studied.

Pruebas	Muestra A	Muestra B
A 50°C	16	15
Contenido de residuo mezcla asfáltica %	57.4	61.6
Asentamiento a 5 días, %	1.2	2.6
Retenimiento en la malla No. 0.850, %	0.14	0.04
Penetración a 25°C	93	55

Table 2 Results from evidence to the asphalt emulsions

Likewise, table 3 shows the results of the tests carried out on the mixture of petrous material

Pruebas	Muestra de material seleccionado	
	Reciclada	Tradicional
Peso volumétrico seco suelto, kg/m ³	1195	1247
Humedad óptima de la muestra, %	12	10
Cubrimiento, %	95	97
Manejabilidad	Buena	Buena
Adhesividad	Buena	Buena
Compresión sin confinar, kg/cm ²	7.2	7.3
Perdida de estabilidad	40.2	30.7

Table 3 Results of tests on mixtures of petrous material

Finally, the cost analysis is detailed in the table.

Partida	Mezcla normal	Mezcla reciclada
Materiales	95	76.77
Basicos	320	280.35
Total costo directo	415	357.12

Table 4 Comparison of costs per cubic meter of asphalt mixtures

With these values, it is possible to estimate that the use of the recycled mixture allows a saving of 14% at direct cost compared to the cost of materials and in the basic costs of the asphalt mixture.

Conclusions

It is shown that the physical characteristics of recycled stone aggregates are very similar to traditional aggregates.

The product obtained from the recycling of construction and demolition waste meets the requirements for an asphalt.

There are no significant differences in the mechanical behavior of the recycled stone material with respect to the traditional one.

The behaviour of the potholes made with both samples was very similar and they did not show deformations or considerable detachment.

Overall, the recycled mix costs 14% less than the traditional mix at direct cost.

It is recommended to subsequently validate the research by adding the additives to the asphalt (wet method). Asphalt mixtures modified with recycled materials show a decrease in stability by 10 to 13% with respect to the conventional mixture in the optimal percentage of asphalt and additive.

This type of blend shows a tendency to improve unit weight properties. The best behaviour of asphalt mixtures is obtained when the asphalt is improved with chemical additives.

In the optimal percentage of this mix, the unit weight is similar, the percentage of voids is higher, and the stability is 0.76 times lower than that of the conventional mix.

Modified asphalt mixtures with recycled materials and chemical additives have the same behaviour as conventional ones, especially in stiffness, resistance to deformation and unit weight.

Acknowledgements

The researchers thank the Science and Technology Research Department (DICYT) of the San Francisco Xavier University of Chuquisaca for the support provided in the development of this work.

Construction elements for ecological houses

Elementos constructivos para casas ecológicas

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DOI: 10.35429/JCE.2021.13.5.7.12

Received 15 January, 2021; Accepted 30 June, 2021

Abstract

This research was carried out to learn about the use of reject plastic "PET" (Polyethylene Terephthalate), coming from plastic containers and other plastic waste, to make mortars that can be used for the manufacture of construction elements. The plastic waste is ground up and put into a combination of cement and a chemical additive that improves the strength of the mortar. Many bricks and tiles were made from this combination; many of them have presented less unit weight, acceptable absorption and good resistance in accordance with the required standards. The following investigation allows the use of three, recycling, reduction and reuse of R, which is an excellent lemma to put into practice.

Constructive elements of recycled plastic, Environmental pollution, Social houses

Resumen

Esta investigación se llevó a cabo para conocer el uso del plástico de desecho "PET" (tereftalato de polietileno), procedente de envases de plástico y otros residuos plásticos, para hacer morteros que puedan utilizarse para la fabricación de elementos de construcción. Los residuos de plástico se trituran y se introducen en una combinación de cemento y un aditivo químico que mejora la resistencia del mortero. Con esta combinación se han fabricado ladrillos y tejas, muchos de los cuales han presentado un menor peso unitario, una absorción aceptable y una buena resistencia de acuerdo con las normas exigidas. La siguiente investigación permite el uso de tres, el reciclaje, la reducción y la reutilización de R, que es un excelente lema para poner en práctica.

Elementos constructivos del plástico reciclado, Contaminación ambiental, Casas sociales

Citation: FLORES, Víctor, ROJAS, Jesús, TORRES, Rodrigo, VALLEJOS, Rolando, FLOWERS, Paola and FLORES, Mariana. Construction elements for ecological houses. Journal Civil Engineering. 2021. 5-13:7-12.

† Researcher contributing as first author.

Introduction

Every day we dispose of large amounts of polymers in the form of plastic bottles, cartons and yogurt containers. Experts estimate that 25% of polymer waste cannot be recycled, for three main reasons: it contains mixtures of different types of polymers; it is not economically profitable; and it is a very messy process.

These plastic bottles are the most rebellious when it comes to transforming. Outdoors they lose their tonicity, fragment and disperse. Buried, they last longer. Most are made of polyethylene terephthalate (PET), a tough material to crack because it is immune to different types of microorganisms.

In the present investigation, disposable bottles were used, made up of PET and plastics from candy packaging, BOPP (Bioriented Polypropylene) and PVC (Polyvinyl Chloride).

The construction elements that were designed with these materials are bricks and tiles.

The use of recycled materials in construction reduces environmental pollution, contrary to what usually happens when natural raw materials are used.

It can be said that it is a "clean and cleansing" technology, because the manufacturing procedures do not pollute the environment, and because waste is used as raw material.

In the case of PET containers, there are other recycling procedures in the world for various applications, but more complex than the one used in this research.

In this case, it is not necessary to remove labels or lids prior to the grinding process, small amounts of soil or dirt are admissible in the containers, and the material will not be melted.

Background

Today's recycling process is crucial to dealing with the growing volume of waste we produce, but researchers are looking for alternative solutions.

A group that has partners from Spain, Latvia and Lithuania assures that it is ready to launch an ecological solution for the management of plastic waste on the market. The SANDPLAST project, funded by the EUREKA programme, has developed a technology to produce concrete construction materials using polymer waste and inert fillers.

Valdis Leitlands has helped design this technique within the project and is convinced of its commercial potential and has therefore founded Partneris LV, a spin-off company that aims to create new construction materials from polymeric waste. His company has joined forces with Uniland Concrete, which has the capacity to produce two million cubic meters of ready-mix concrete a year, to help him test products created using this technique and find markets. Lithuanian partners also participate in the project.

The waste we produce is infinite and the manufacture of classic brick is a true ecological disaster, because it is made with humus that takes thousands of years to form and in open-air kilns, as was the case in Babylon.

In other words, on the one hand we bury the garbage and, on the other, we devastate the fertile land. We propose a technology that helps alleviate both problems, but is also cheaper, very efficient from the point of view of insulation and easy to manufacture." Source- article in the Argentine newspaper La Nación.

Problem statement

Falta of proposals to consolidate this type of mix using recycled plastic as raw material. Polymers are polluting products of the environment and do not have biodegradable properties, but rather last over time, constituting a problem for the environment.

Objectives

General Objective

Make mixtures of cement and plastic aggregates for the manufacture of bricks and tiles usable in ecological-social constructions.

Specific objectives

- Contribute to the reduction of contamination by plastic containers (polyethylene-terephthalate).
- Determine and evaluate the dynamics of the mix.
- Determine and evaluate resistance by laboratory tests.

Hypothesis

With the addition of recycled plastics, PET, BOPP, in traditional mortars, it is a matter of obtaining a construction material with characteristics like conventional ones, providing lower specific weight and reaching the resistance required by the standard. In this way we contribute to recycling and non-pollution by plastic waste.

Justification

These plastic bottles are the most rebellious when it comes to transforming. Outdoors they lose their tonicity, fragment and disperse over a very long period of time (100-1000 years). Most are made of polyethylene terephthalate (PET), a tough material to crack as it is immune to different types of microorganisms.

The construction elements that will be designed with these materials will be bricks and tiles, helping to control the environmental pollution produced by PET bottles, BOP and other plastic materials that do not degrade easily, providing an economic technology, fast learning, minimum equipment and good living conditions, one of the factors that most reduces productive activity in the rural sectors of the department of Chuquisaca and of Bolivia in general is the backwardness of the towns due to the lack of initiatives that allow for short-term solutions, as is the case of the mixtures of cement and plastic, which in addition to controlling environmental pollution are cheaper and offer a more aesthetic panorama.

Materials and methodology

The materials used are:

- Recycled plastics.

- Cement.
- Water.
- Sand.
- Chemical additives (Sika FF-86).
- Metal models.
- Concrete mixer.
- Sieves
- Other materials:
 - Pallas.
 - Compactor rod.
 - Demonstrate through laboratory tests resistance and durability mechanisms for each of the construction prototypes.
 - Demonstrate through tests the resistance to tensile and compressive stresses.
 - The final test must allow validating the application of mixtures with polymers, for the use of mechanisms that do not harm health or the environment.

Pressmen

Performance of standardized tests in laboratories, to establish physical properties.

- Mill (crusher)

Methodology

This research work was carried out using a methodology with high experimental content. For the manufacture of the cement-plastic mixtures, a granulometry was used for the sand and another for the plastic particles with a fineness modulus of 4.25 in the case of bricks and tiles.

Activities

- Revision of information.
- Perform conceptual design.

- Carry out the experimental engineering design.
- Demonstrate through tests the influence of the hardness and the dynamics of the mixtures.

Comparative economic evaluation of the construction elements developed. The dosage of the mortar is 1:4 for both the brick and the tile, the chemical additive is added to the mixing water, in a percentage of 0.5% of the weight of the cement. To remove the percentage of moisture from the aggregates (sand). First, we proceeded with drying in the sun, continuously removing the samples to be used.

Once the drying of the samples was concluded, the respective sieving was carried out to obtain the granulometry required by the standard. The PET was crushed with a mill designed for this purpose.

The PET particles were mixed with cement in a concrete mixer, then water with incorporated chemical additives (sika ff86) was added.

When this mixture acquired a uniform consistency, it was poured into a metal mold.

The compaction of the mixture and the position of the bricks and tiles was carried out.

The control specimens were made together.

They were left outdoors for a day and then moved to a container for curing with water, in which they remained for seven days.

The test pieces broke after 28 days in a laboratory, which gave us a compressive strength required by the standard.

LI remove the bricks and tiles after 7 days of curing and store them until they are 28 days old.

Composición Granulométrica (Norma Iram1627)			
Tamiz	Peso Retenido (g)	% Retenido	% Ret. Acumulados
4 = 4.75 mm	2.5	0.278	0.278
8 = 2.40 mm	97.0	10.790	11.068
16 = 1.20 mm	191.5	21.301	32.370
30 = 0.59 mm	297.0	33.037	65.410
50 = 0.29 mm	236.0	26.250	91.660
1 100 = 0.15 mm	56.0	6.220	97.880
Mf = 2.99			

Table 1 Resistance and stability tests (emptying)

Dosage

Flake aggregate replacement percentages

15% of the weight of sand was replaced in its place, 1 kg of PET flakes, the incorporation of plastic in the composition of the mixture produced changes in the characteristics of the mortar, not gradually proportional to the increase in the % of incorporated flakes, but appreciable modifications were observed for percentages specific for PET aggregate.

Sika fluidifying additives (Sika ff86) added to the mixtures were used, according to the usual dosages. A weight ratio of one part of cement per four of aggregates (1:4) was adopted. The PET flakes were added in different percentages according to the portion of sand that you want to replace

Preparation of mortars

Two specimens were moulded for each mixture or proposed dosage, one containing fluidizer and the other that did not, of which two were analysed at the age of 7 days and 2 at the age of 28 days, for compressive strength tests in both cases. The method of mixing, filling molds and compaction was carried out as indicated by the standard. In all cases it was determined previously, in the fresh state, and the fluidity

The study proceeded as follows:

All kinds of plastics were used for its preparation, which were crushed in a mill designed for this purpose, and then mixed with the cement and a chemical additive in the water, which improves the adhesiveness of the plastic particles with the cement.

The slow biodegradability of plastic is a problem on many occasions, in this case it becomes a great ally of this material.

The PET particles were mixed with cement in a concrete mixer, then water was added with chemical additives incorporated. When the mixture had reached a uniform consistency, it was poured into moulds. consistency, it was poured into metal moulds and compacted. metal moulds and then compacted.

Results

The construction elements developed have sufficient technical quality for their application.

The physical properties of the same described below were established by carrying out tests in laboratories.

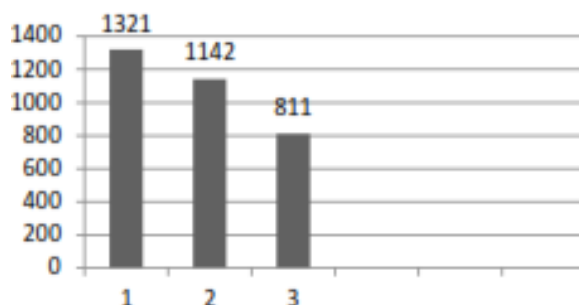


Figure 1 Specific Weights

1. common ground brick 1321 kg/m³.
2. bricks with crushed plastic 1142 kg/m³.
3. tiles with crushed plastic 811 kg/m³
Mechanical resistance: It is lower than most of the traditional construction components, but enough so that they can be used in houses with an independent structure. The brick with PET has a characteristic resistance of 4 Mpa.

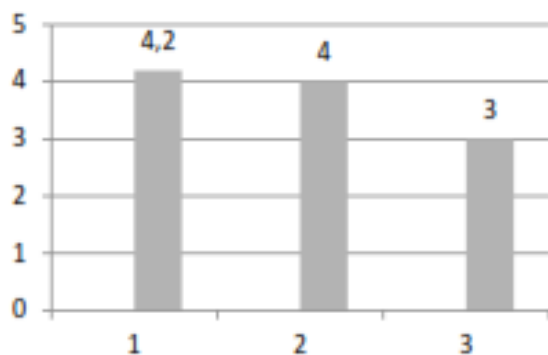


Figure 2 Resistance graph

1. Common ground brick 4.2 MPa
2. Bricks with crushed plastic 4 MPa
3. Tiles with crushed plastic 3 MPa

Due to the difference in unit weight between the aggregate and the flakes, the PET was replaced by an apparent volume equivalent to that of the aggregate to be replaced.

Serie de probetas	% Sustitución de arena por PET	Cemento kg	Arena kg	Escamas de PET kg	Agua cm ³	Aditivo %
1	15%	1	4	1	900	No Contiene
2	15%	1	4	1	600	2.0 Fluidificante sika

Table 2 Costs

The estimated price of each brick is detailed in the following table:

materiales	unidad	cantidad	precio(unitaio)	parcial(bs)
cemento	kg	1	0,88	0,88
agua	cm3	900	0,033	0,030
arena	kg	4	0,016	0,1
aditivo	cm3	10	0,04	0,4
plastico	kg	1	0	0
total				1,41

Table 3

Where the price for each brick is 1.41 bs, the elaboration of construction elements with this technology has a cost like that of other traditional construction elements.

The unit production cost of a PET brick is 30% higher than that of a common fired earth brick. The saving is verified in the fact that enclosures can be built with thicknesses less than those of traditional enclosures, due to their good thermal insulation, (which takes up less space on the ground and uses less joining material and is lighter (with which saves on transportation.

The manufacturing technique is very simple, easily reproducible by non-specialized personnel. No large-scale infrastructure is necessary to produce the material, or land for aggregate extraction.

Discussions and recommendations

It is recommended to subsequently validate the research by adding the plastic additives to the mortar.

In the PET and cement developed by CEVE, it is observed:

- The PET has a specific weight that is 15.5% lower than the common one.
- The PET has a coefficient of thermal conductivity that is 80% lower than that of the common one.
- The PET has a compressive strength that is 50% lower than that of the common one.

- The PET has a percentage of water absorption that is 11.5% lower than that of the common.

Conclusions

In the fresh state, the mortars presented little plasticity and little cohesion for the mixture with flakes. The lack of docility and homogeneity of the mixture, caused a decrease in settlement (after compacting), the reason, in our opinion, was the inadequate granulometry of the PET flakes, provided by the mill.

Doing an analysis of the prices of materials, it is concluded that the tile and the brick are cheaper with a cost of 1.41 Bs, the common brick has a cost of 1.5 Bs for each unit.

PET is recycled through a very simple and cheap process since it does not need to be clean, it can contain dirt, grit, etc. without affecting its good properties. PET containers are milled with labels and lids, and the presence of other types of containers (PP, PVC, etc.) is also accepted.

Acknowledgements

The researchers thank the Science and Technology Research Department (DICYT) of the San Francisco Xavier University of Chuquisaca for the support provided in the development of this work.

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Recovery of saline soils with the incorporation of calcium sulphate hemihydrate ($\text{Ca}(\text{SO}_4) \frac{1}{2} \text{H}_2\text{O}$) in the community of Yotala

Recuperación de suelos salinos con la incorporación de sulfato de calcio hemidrato ($\text{Ca}(\text{SO}_4) \frac{1}{2} \text{H}_2\text{O}$) en la comunidad de Yotala

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DOI: 10.35429/JCE.2021.13.5.13.30

Received 20 January, 2021; Accepted 30 June, 2021

Abstract

The study was carried out in the town of the department of the province of Yotala Oropeza Chuquisaca, having obtained the answers of each experimental unit, the objectives proposed in the investigation are achieved. By interpreting the water analyzes we could classify Yotala irrigation water as average salinity water (C2) that can be used as long as there is a moderate degree of leaching. In almost all cases, and without requiring special salinity control practices, moderately salt tolerant plants can be produced. They also say that the irrigation water is a low sodium (S1) water that can be used for irrigation in most soils with a low probability of dangerous levels of exchangeable sodium. However, sensitive crops, such as certain fruits and avocados can accumulate harmful amounts of sodium. At a pH of 7.5 obtained we can say that our sample slightly basic information, based on the reference values (6.0 to 9.0) is in the common range of water for irrigation. In the interpretation of water that have been made, we can say that the irrigation water used in Yotala is optimal for irrigation and is not causing the accumulation of soluble salts in the soil.

Resumen

El estudio se realizó en la localidad del departamento de la provincia de Yotala Oropeza Chuquisaca, habiendo obtenido las respuestas de cada unidad experimental, se logran los objetivos propuestos en la investigación. Interpretando los análisis del agua pudimos clasificar el agua de riego de Yotala como agua de salinidad media (C2) que puede ser utilizada siempre y cuando exista un grado moderado de lixiviación. En casi todos los casos, y sin requerir prácticas especiales de control de la salinidad, se pueden producir plantas moderadamente tolerantes a la sal. También dicen que el agua de riego es un agua baja en sodio (S1) que puede utilizarse para el riego en la mayoría de los suelos con una baja probabilidad de niveles peligrosos de sodio intercambiable. Sin embargo, los cultivos sensibles, como ciertas frutas y aguacates, pueden acumular cantidades perjudiciales de sodio. Con un pH de 7,5 obtenido podemos decir que nuestra muestra de información ligeramente básica, basada en los valores de referencia (6,0 a 9,0) está en el rango común del agua para riego. En la interpretación del agua que se ha realizado, podemos decir que el agua de riego utilizada en Yotala es óptima para el riego y no está provocando la acumulación de sales solubles en el suelo.

Water soluble salts of salinity, Medical

Sales solubles del agua de salinidad, Médico

Citation: FLORES, Eddy, FLORES, Juan and TÓRREZ, Jorge. Recovery of saline soils with the incorporation of calcium sulphate hemihydrate ($\text{Ca}(\text{SO}_4) \frac{1}{2} \text{H}_2\text{O}$) in the community of Yotala. *Journal Civil Engineering*. 2021. 5-13:13-30.

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Introduction

Over time, the specifically agricultural areas of the entire Andean region, about the nature of the soil, are being affected in their productive capacity by the accumulation of soluble salts; caused in part by the misuse and inadequate management of the land; Currently it is observed that it is being caused by water pollution and sudden changes in climate.

The salinity problem occurs more frequently in arid and semi-arid regions, due to the lack of rainfall and high evapotranspiration, which tends to easily accumulate salts in the superficial part of the soil, manifesting itself with the presence white crusts.

Nature is so vast that it cannot be controlled to reduce the outcrops of salts in the environment.

In Bolivia, salinity affects the Bolivian highlands and the valleys (Chuquisaca, Cochabamba). The incidence of which is more frequent in areas with low irrigation and poor drainage, such as in the department of Chuquisaca.

In our environment there are huge extensions of valley headwaters with potential for agricultural productivity; but due to the outcrop of salts, it is not possible to take full advantage of the use of these lands because the salts are a limiting factor.

Since the population increases annually, and the food supply is considerably reduced to such an extent that year after year, there has been a gradual regional decrease due to the productive degradation of agricultural soils, particularly in our country.

To improve the productive capacity of saline soils, it is necessary to take precautions in the management or use of land to raise the quality and quantity of the products; on the other hand, Richards (1980) has suggested certain arbitrary relative salinity factors, such as the selection of salinity tolerant crops and sodic soils.

To improve saline soils, Milton (1998) has carried out a study on this type of soil to control the outcrop of salts using calcium sulphate hemi-hydrate treatments (baked plaster), at the end he applied washing to leach cations such as Ca, Mg, Na, K, etc. Among which are ammonia; the author indicates that the reduction was 41.2% of electrical conductivity (CE) with the application of 1 tn/ha of calcium sulphate, in the same way it has decreased with the application of 1mmho/cm for every 0.30 mm of the water sheet added.

To recover the saline soils in this study, it was based on the direct use of four levels of calcium sulphate hemi-hydrate or agricultural gypsum with the provision of methods that allowed measuring the resolution of outcropping of salts.

Background

In Bolivia, salinity affects the highlands, such as the departments of Oruro, Potosí, La Paz, and the valleys such as Chuquisaca, Cochabamba, and Tarija, with which it often occurs in low-irrigation and poor-drainage regions, mainly as in the community of Yotala and Sucre.

On the other hand, it is pointed out that the headwaters of the valleys have potential for agricultural production, due to the climatic characteristics that are favourable. However, due to the flowering of saline soils that affect the fertility capacity of soils, they are not used to the maximum in the affected regions. It can also be mentioned that the population increases annually, and the yield of agricultural products is considerably reduced by the salt factor.

The problem of salinity occurs more frequently in arid and semiarid regions due to low rainfall and high evapotranspiration, in the same way one of the factors that affects the productive capacity of soils is the poor management of agricultural work in the production process, which leads to the degradation of the productive capacity of soils, and low yields in agricultural production in various regions that are affected by this problem.

For all the above, in the present research work it is proposed to carry out a preliminary study in the community of Yotala, using calcium sulphate hemi-hydrate $\text{CaSO}_4 \cdot 1/2\text{H}_2\text{O}$ with different levels per hectare as treatment. To contribute to society and be able to solve the problem of salinity in agricultural soils.

Problem statement

In the community of Yotala it appears frequently salinity in the lands in which it is presented under irrigation, which is a negative factor for agricultural producers, since each year that passes the yield of agricultural products is reduced. Faced with this situation, there is sufficient research on the salinity of agricultural soils to be able to solve the problem that affects all of Bolivia. Importance or justification.

To improve the productive capacity of saline soils in our environment, it is necessary to take precautions in the management of agricultural work to reduce the acceleration of soil salinity and carry out research on salinity; through which the yield can be maintained, or the quality and quantity of agricultural products can be increased. Through this research, training and information can be provided to agricultural producers, mainly small producers with low economic resources, and likewise reduce the acceleration of food insecurity that occurs in our environment and worldwide.

These investigations are supported below:

To improve saline soils, Milton (1998) has carried out a study on this type of soil to control the flowering of salts using calcium sulphate hemi-hydrate treatments (baked gypsum), at the end he applied washing to leach out cations such as Ca, Mg, Na, K etc.

Among which are ammonia; the author indicates that the reduction. the application of 1 tn/ha of calcium sulphate, in the same way, with the application of the treatment, has decreased 1mmho/cm for every 0.30 mm of the layer of water added.

The present research work takes into consideration all the aspects mentioned, for this reason it is proposed to carry out a preliminary study in the community of Yotala and mainly in its agricultural community, using calcium sulphate hemi-hydrate, $\text{Ca}(\text{SO}_4) \cdot 1/2\text{H}_2\text{O}$ as treatment $1/2\text{H}_2\text{O}$.

To have basic and necessary information to guide in future works framed in this area.

To recover saline soils in this study, it will be based on the use of calcium sulphate hemi-hydrate, $\text{Ca}(\text{SO}_4) \cdot 1/2\text{H}_2\text{O}$, at four levels with provision of a method that allows measuring the resolution of salt outcrop.

This research in which it is intended to use a treatment with calcium sulphate hemi-hydrate, which is very commercial and has an economically accessible price by 95% compared to the use of chemical fertilizers. This is favourable for small producers in our environment.

Research objectives

General objective

To determine the degree of recovery of saline soils with the incorporation of calcium sulphate hemi-hydrate in the community of Yotala.

Specific objectives

- Carry out and interpret a water and soil analysis before the application of the improver, to identify the initial value of the variables involved in the improvement process, such as pH, electrical conductivity, number of dissolved salts, etc.
- Apply the improver to the ground in three different amounts, leaving witnesses to compare the effects caused by the improver.
- Through the interpretation of a soil analysis, determine the effects of doses of calcium sulphate hemi-hydrate according to the level of reduction of both soluble salts in saline soils and soil pH.

Hypothesis

The application of different doses of $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ to saline soils influences the recovery of its productive capacity.

In saline soils, its productive capacity is improved with the incorporation of calcium sulphate hemi-hydrate, due to the effect of the amendment, agricultural yield will be increased.

Operationalization of variables

Our variables will be:

- Amount of gypsum used for the treatment. The degree of recovery of saline and sodic soils will depend on this variable.
- pH. The classification of the soil as acidic or basic/alkaline will depend on this variable.
- Irrigation water. This variable will allow us to know if the accumulation of soluble salts is caused by irrigation water.
- Crop production. With this variable we can determine the degree of soil improvement. Namely, a larger stem diameter, larger size and crop production will be obtained.

Materials and Methodology

In the present investigation, the experimental method will be used to obtain chemical results of soils, for which it is described below:

Description of the study area

Location

The community of Yotala is located northeast of the department of Chuquisaca, 16 kilometres from the city of Sucre, capital of the department. It limits to the north with the municipality of Sucre, to the east with the province of Yamparaez and to the south-west with the department of Potosí. The municipality is in the first municipal section of the Oropeza province.

With the respective geographic coordinates $19^{\circ}9'45''\text{S}$ $65^{\circ}15'55''\text{W}$. at a height of 2,254 meters, max: 2,867 meters above sea level. It is a passing town, since it is located a few meters from the interdepartmental highway that connects the cities of Sucre and Potosí.

Weather

The study area is considered as the head of the valley because the climate varies between 8°C to 25°C , with a relative humidity of 77%; wind speed 9.66km/h, with approximate rainfall of 60 to 1200 mm per year.

Floors

The soils of the region are characterized by the presence of soil with considerable salinity, with a loamy-clay texture, with low permeability. the presence of soluble salts such as Ca, Mg, K and Na in less quantity of sulfates and bicarbonates of calcium and magnesium. With a pH that is presumed between 7.8. to 8.9 (Acid).

Materials

In the present investigation, agricultural field material and flexo, scale, camera, GPS, wood or venestas for parcel signs, paint, nylon bags, and stationery will be used. (Letter and legal-size bond paper, markers, envelopes, etc.)

Treatment material

In the present research work, calcium sulfate hemi-hydrate will be used as a treatment material for saline soils, it is an element that reduces soluble salts and through which it will be possible to improve the productive capacity of soils and improve fertility.

Methodology

Diagnosis of the Yotala community

For the present investigation, a diagnosis will be made in the study area or the community to verify the soluble salts in the arable plots in the same way as they will perform and interviews to the pessimal producers and the zone for get specific information.

As is known, each year that passes, the soils produce with lower agricultural yields, a high percentage of pest attacks on plants and the soil texture becomes clayey, due to salinity. In the same way using faith utilizes the texture of the earth becomes more clayey. water sampling.

In the present investigation, water sampling will be carried out for laboratory analysis according to established laboratory standards.

For the titration of cations, anions, and pH.

Soil sampling

The sample will be carried out according to the TRUORG or Olsen (CIAT) method, in a zigzag pattern at a depth of 60 to 90 cm. Once the sub-samples have been obtained, a quartering will be carried out to obtain a kilo of sample. Then the respective interpretation will be made from the data obtained in the laboratory.

Treatment dose

The doses will be used at four levels per hectare and a control, in this investigation the table is presented:

Dosis por hectárea	Dosis en tratamiento 50m ²
1300 kg /ha de Sulfato de calcio	14kg/50m ²
1500 kg /ha de Sulfato de calcio	20kg/50m ²
1700 kg /ha de Sulfato de calcio	24kg/50m ²
	Testigo o sin tratamiento

Table 1 Treatment application

Treatment application

The incorporation of the treatment will be applied once the plot has been irrigated, the soil will be broken up with a yoke, and then the calcium sulphate will be applied in a broadcast application. Once it is applied, the soil will be stirred again and then irrigated after a week to keep the soil moist and to achieve the chemical reaction.

A sketch of the plot is shown below:

I	II	III	IV	V
T1	T3	T2	T1	T3
T0	T0	T0	T0	T2
T3	T2	T0	T0	T1

Reference:

Treatments: T1, T2, T3

Controls: T0

Total plot area: 200m²

Plot unit: 50m²

Contextual framework

This study was carried out in the locality of Yotala. In the Oropeza Province of the Department of Chuquisaca, on the premises of the University Experimental Farm -"Villa Carmen", in the second orchard, belonging to the Faculty of Agricultural Sciences of the U.M.R.P.S.X.CH. Geographically, it is located between the parallels 65° 15'25" West longitude and 19° 09'28" South latitude, at an altitude of 2515 m.a.s.l., 15 km from the city of Sucre on the road that connects with the department of Potosí.

Theoretical framework

Origin of the nature of saline/sodic soils

Origin of salinity

According to Richards (1983), saline soils are found in arid and semi-arid climates where evapotranspiration is higher than precipitation. In practice, saline soils do not exist in humid climates, the salinity problem is of greater economic influence due to the consequence of soil irrigation, even a non-saline soil could become saline due to the deposition of salt in the soil and irrigation water, salinity can originate from several causes:

a) Natural causes

They are due to natural weathering of rocks and minerals, volcanic activity, movement of salts by the wind, the proximity of the sea which contains salts in large quantities, results of biological phenomena, arid climates with high evapotranspiration.

b) Human causes

These are due to the action of man in the environment and can be: the generation of salts because of industrial waste, waste from industries from industrial waste, irrigation with very saline solutions or water of poor quality and in continuous form, in regions of high salinity. water, in arid regions where the lack of rainfall prevents the washing of soils and salts tend to accumulate in the soil. and salts tend to accumulate forming white crusts on the surface of the soil.

On the other hand, Eduard, (2000) mentions that in the headwater areas of valleys, salts originate more frequently because of the salts originate more frequently due to the application of irrigation with salty water, which causes the salts to evaporate to the superficial part of the soil. the soluble salts evaporate to the surface of the soil, which is why the soil is covered with a white mantle (white crusts) in these areas. (white crusts) in these soils the inones are present in chemical substances, and with the course of time they accumulate In the course of time, they accumulate in large quantities, so the soil has a susceptibility to become saline.

Susceptibility to become saline or sodic, and the soluble salts are harmful to agricultural producers. In extreme cases, in saline soils, the electrical conductivity is higher than 4.0 millimhos/cm³/year. 4.0 millimhos/cm and the percentage of sodium absorption is 13 to 18.

According to Storie (1970), the interpretation of the minerals, with the course of time are transported to the lower soil layers, the minerals are therefore detained in soils that are under irrigation, and seawater, river deltas in the headwaters of valleys are susceptible to salinity, which is most often observed in arid and semi-arid regions, due to low rainfall and high temperatures. Sometimes soluble salts move below the subsoil, but surface water acts as a solvent of salts, so irrigated land is exposed to flooding by torrential water carrying minerals.

Cepeda (1991), indicated that in arid regions, where there is little rainfall and high temperatures, there is always an accumulation of soluble salts such as Ca⁺, Mg⁺, K⁺, Na⁺ and other cations, but during the rainy season, these salts are infiltrated into the soil towards the soil, These salts are infiltrated into the lower layers of the soil, after the rainy season the salts return to the surface of the soil, therefore white crusts are observed, due to the intensive evapotranspiration, the groundwater generally contains soluble salts, therefore this type of soil is only suitable for resistant crops. Therefore, only saline-resistant crops thrive in this soil type.

The same author mentions that the upwelling of salts is due to the weathering of minerals that release atmospheric carbon dioxide (CO₂), also calcium hydrates, magnesium and potassium are released in the same way, this is due to the incorrect drainage system, magnesium and potassium are also released in the same way, this is due to an inadequate drainage system, This is due to the inadequate drainage system, which is insufficient for the evacuation of rainwater (torrential), when these waters stagnate in the lower When this water stagnates in the lower parts, it evaporates in large quantities and leaves the soil with white crusts on the surface. The irrigation water also plays a role, e.g. the application of water with a high concentration of salts that water with a high concentration of salts, which raises the underground water table, i.e. in the event of flash floods, the salts are concentrated in the root zones of the plants, which leads to the translocation of nutrients and the translocation of nutrients and water uptake.

The Food and Agriculture Organisation of the United Nations (FAO), (1986), (1986) confirms that saline soils are most frequently observed in arid and semi-arid regions, where rainfall is low and temperatures are high, the fundamental cause being low rainfall and intense evapotranspiration.

The fundamental cause is low rainfall and intense evapotranspiration, which causes salts to build up in the surface part of the soil, so that the plant does not thrive in these soils, and this is linked to topographical features, flooding of the this is linked to topographical features, flooding from torrential waters that are stagnant in the lower part of the working lands. This tends to degrade the productive capacity of the soils. This occurs more frequently at the headwaters of valleys where the land is under irrigation.

According to Bukman and Brady, (1993), when drainage is insufficient in agricultural land, there is a tendency to accumulate more water in the soil. soil, salts tend to accumulate more easily in the horizons of the soil profile. in arid areas due to unfavourable climatic conditions.

Factors influencing saline/sodic soils Richards, (1993), points out that salt-laden waters are the result of the weathering of minerals. The salts accumulate in the crusts in two ways: underground and in depressions; this causes saline groundwater tables, on the soil surface there are puddles of water, lagoons, etc. This is due to the deficiency of natural drainage, in the same way the mineralisation of saline soils is due to the main causes which are climatic factors, therefore the soil structure is unstable because the organic matter content is poor, due to this they are not suitable for general agricultural use because the salts cause serious problems.

In this respect, Idea Books, (1999), mentions that salts dissolved in water hinder the absorption of nutrients and water by plants, on the other hand, salts produce phytotoxicity in the germination phase of seeds, as well as in the first phases of seedling development, which can cause their death.

Bukman and Brady, (1980), point out that saline-alkaline soils are due to the precipitation of cations such as Ca, Mg, K, Na, as well as lower proportions of chlorides and sulphates and even bicarbonates, due to which the salinity of the soil increases over time, so that the pH varies between 7.5 and 8.5, so that the concentration of salts is high.

Research carried out by Colacelli reveals that the factors that influence alkaline soils are those that have a high salt concentration. alkaline soils are those that have a significant amount of sodium ions with undesirable properties, with low permeability, and with a low undesirable property, low permeability, unstable aeration, so it is necessary to correct the soil structure to increase aeration. correct the soil structure to increase productivity.

Characteristics of saline soils FAO (1986), defines that the electrical conductivity of the base saturation extract in saline soils is higher than 4 mmhos/cm at 25C, the value of the sodium adsorption rate is lower than 15 and the soil pH ranges from 7.5 to 8.5, but it is possible to recognise with the naked eye when the soil is covered by a white (greyish) mantle, also the excessive concentration of salt, hinders the normal development of plants, especially by the deficiency of water and nutrient adsorption, because the permeability is very low, the structure and texture are unstable. The permeability is very low, the structure and texture are unstable.

Cepeda (1991) indicates that saline soils usually contain more than 0.2% of soluble salts. soluble salts, which increases the osmotic pressure of the plant, thus hindering the adsorption of nutrients and water to the plant. adsorption of nutrients and water to the plants, on the other hand, the pH rises between 7.5 and 8.5 because the salts are displaced in water, this This happens during the rainy season because the salts are concentrated in the lower part of the soil. in the lower part of the soil.

Bohn, (1993), classifies saline soils on the basis of electrical conductivity (E.C.), which has established a limit of 4dsm-1, which is why the Soil of Science Society of America has recommended lowering the standards for saline soils. recommended lowering the standards for saline soils to 2dsm-1, so that the base saturation extract is detrimental to plant development, even the characteristics could be observed with the deformation of the leaves, bluish-green colour, stunted size.

According to Richards (1993), this type of soil is formed as a result of the combined process of salinity and sodium accumulation, moreover, soils were classified with respect to the conductivity of the aqueous saturation extract in five classes:

- a) Non-saline soil, those with conductivity values of 2 mmhos/cm or less and according to the effect of plant development, (low salinity degree).
- b) Non-saline soil, the E.C. values between 2 and 4 mmhos/cm, with a slight effect on plant growth, (low salinity degree). plant growth, (low salinity).
- c) Saline soil with an E.C. value of 4 to 8 mmhos/cm, where the yield of the crop is reduced (degree of salinity mild). (High degree of salinity).
- d) Soil with 8 to 16 mmhos/cm of E.C., in which there are few crops that can withstand these conditions, (high salinity degree). these conditions, (very high degree of salinity).
- e) Soil with values higher than 16 mmhos/cm of E.C., the restrictions for cultivation are greater than the previous one, (extremely high degree of salinity). Saline soils tend to have a high concentration of salts, but little exchangeable sodium (Na⁺).

In this respect, Idea Books (1999), defines the characteristic of salinity, indicating that it is due to poor drainage, especially in arid and semi-arid regions, in these areas rainfall is low and evapotranspiration high, this tends to have an abundance of salts, sulphates, chlorides of Na, Ca, Mg and K, these elements are concentrated in the "A" horizon, this prevents the adsorption of nutrients and water to the plant.

According to the soil recovery analysis (2000), it is recommended to wash the soils with abundant water, taking into account the drainage to avoid water stagnation, always taking into account the solubility of salts, which decreases at low temperatures, because in winter evaporation is high and may require several washes. The electrical conductivity of the saturation extracts of these soils is less than 4 mmhos/cm, but the percentage of exchangeable sodium is less than 15.

Research carried out by Bohn, (1993), reports that saline soils are also caused by human activity, in that salts are transported by irrigation, where they run off on the surface with the application of water, thus increasing salinity in headwater valley soils, the main cause being high temperatures, evaporation and transpiration.

With reference to this problem, Idea Books, (1999), indicates that saline soils have a high content of soluble salts, this concentration prevents the plant from adsorbing nutrients due to the difference in osmotic potential, when its conductivity exceeds 4 mmhos/cm the soil characteristics are modified, where it is most concentrated is in the superficial part of the -A horizon, based on these aspects the author classifies the soils as shown in the table:

Grupo de suelo	Conductividad específica del estrato de saturación a 25°C en mmhos/cm C.E.S.	Saturación de sodio de la capacidad de intercambio catiónico
Salinos no sódicos	>4	<15
Salinos sódicos	>4	<15
Sódicos no salinos	<4	>15
No sódico, no salino normal	<4	<15

Table 2 Classification of soils with salinity problems according to their chemical priorities

Characteristics of sodic soils

Studies carried out by Historie (1983), reveal that sodic soils are those with an excess of sodium, with a pH greater than 8.5 to 10, the dissolution of organic matter is dark in colour with the name of -black alkali with flocculated clay subsoil and with a high content of absorbed sodium.

On the other hand FAO (1986), mentions that sodium adsorption is higher than 15, even can reach 100; with an electrical conductivity of saturation extract of 4mmhos/cm at 25°C, a pH higher than 8.5, therefore the management of these soils is difficult and their productivity is low, because the salt is dominant, as sodium carbonate causes the cation exchange complex, in turn also causes the dispersion and translocation of the particles of soil colloid, all this causes a deterioration in the physical conditions of the topsoil.

This causes a deterioration in the physical conditions of the surface layer of the soil, causing it to crack in dry periods, and can even raise the clods, but in the rainy seasons they become waterlogged because the level of organic matter is very poor, such as calcium, nitrogen and the level of phosphorus is medium, and potassium can be high.

According to Medina (1997), in soils affected by the problem of alkalinity, ions predominate. According to Medina (1997), in soils affected by alkalinity, ions such as Ca^+ carbonate, Mg^+ , K^+ , Na^+ , Cl^+ , HCO_3 and CO_3 predominate, and in some cases NO_3 may be present, and different salts may be formed between these cations and anions, causing difficulties for plant development. The same author describes the compounds that can cause soil salinity as follows:

(a) Chlorides

According to Medina (1997), the derived salts react with some base, such as hydrochloric acid, which are more abundant and more soluble, toxic for crops, the most important being sodium chloride (NaCl), potassium chloride (KCl), (CaCl), (MgCl), all these chlorides become locally important. all of these chlorides become locally important; at the same time they are described in detail:

Sodium chloride: This salt is the main component of soils, in most of them its abundance is due to its great solubility around its abundance is due to its high solubility of about 317 g/l at 20°C. On the other hand, sodium and chlorine are quite toxic for several crops, in most of them. toxic to various crops, in some cases extremely tolerant plants can develop at a concentration of 0.1% NaCl . of NaCl extremely tolerant plants can develop in some cases.

Potassium chloride - This salt is similar to sodium chloride, with a solubility of 30g/l at 20°C with a high toxicity to crops due to the Cl ion, however, it is rarely found in large quantities in the soil, because it is in large quantities in the soil, because potassium is a nutrient element consumed by plants and organisms living in the soil. plants and plant-dwelling organisms.

Calcium chloride: It is a salt with a high solubility of 427 g/l at 20°C, however it is rarely found in abundance, as it generally reacts with the Cl ion in the soil. However, it is rarely found in abundance, as it generally reacts with calcium sulphates and sodium carbonate.

Magnesium chloride - This salt only occurs under extreme salinity conditions; it has a solubility of 410 g/l at 20°C. solubility of 410 g/l at 20°C and is a toxic ion for most crops.

b) Sulphates

The same author mentions that sulphates are derivatives of sulphuric acid and occur in saline-sodic soils as sulphates. sodium-saline soils, such as magnesium sulphate MgSO_4 , sodium sulphate, calcium sulphate and potassium sulphate. potassium sulphate, as follows.

Magnesium sulphate: This ion has a solubility of 262 g/l at 20°C, this salt is very toxic for crops. This salt is very toxic for the crops.

Sodium sulphate - This is one of the common ions found in saline alkaline soils and can also be found in groundwater. It can also be found in groundwater, its influence is of high toxicity, but in comparison to magnesium it is lower. its solubility varies according to temperature, as shown in the table. as shown in the table.

Temperatura °C	Solubilidad gr/l
0	45
10	90
20	185
30	375
40	430

Table 3 Effect of temperature on the solubility of sodium sulphate

Calcium sulphate: This salt is physiologically toxic for the plant and has a low solubility of 1.9 g/l at 20°C, so CaSO_4 is precipitated. between 1.9 g/l at 20°C, so CaSO_4 is precipitated, and therefore does not intervene in the salinity problem. the salinity problem.

Potassium sulphate - This salt has similar properties to sodium sulphate; its toxicity is lower and it rarely accumulates in the water. It rarely accumulates in large quantities in the soil, and its solubility is 180 g/l at 20°C, although it also varies according to the soil temperature. although it also varies according to temperature.

c) Carbonates and bicarbonates

Studies carried out by Medina (1997), show that these salts are derived from the carbonic acid of (H_2CO_3) . $(\text{H}_2\text{CO}_3)_2$, large quantities could be found in saline-sodic soils, the most important ones are $(\text{Na}_2\text{CO}_3)_2$ and $(\text{Na}_2\text{CO}_3)_2$. $(\text{Na}_2\text{CO}_3)_2$, $(\text{CaCO}_3)_2$, $(\text{MgCO}_3)_2$, $(\text{K}_2\text{CO}_3)_2$, all of which are found in smaller quantities in saline soils. in smaller quantities in saline soils.

Sodium carbonate: This salt is very common in alkaline soils and irrigation water, it is highly soluble between 178 g/l at 20°C. soluble at 178 g/l at 20°C, it is extremely toxic to most plants, therefore its presence increases the exchangeable sodium in the soil. its presence increases the exchangeable sodium, resulting in a reduction of soil fertility.

Potassium carbonate - This salt has a low solubility of 0.013 g/l but increases its solubility to 0.014 g/l for its transformation to calcium bicarbonate, its toxicity is not harmful to most plants.

Magnesium carbonate - This salt is soluble at 0.106 g/l but increases in solubility to 0.014 g/l for its transformation into calcium bicarbonates, its toxicity is not harmful to most plants, due to the formation of carbonate by the adsorption of magnesium and clay, it could even be present in arid regions, where it is in arid regions, dolomites such as $\text{Ca Mg} (\text{CO}_3)_2$.

The researcher Colacelli, (2000), states that alkaline soils are those that above 8.2 pH, where they have a significant amount of sodium ion, this type of soil has a higher concentration of sodium ion. This type of soil has a higher concentration of sulphates and chlorides, even the presence of sodium bicarbonates could be found, then due to these the physical and chemical properties of the soil are unstable, with low permeability, with problems of aeration, then the sodic soils are necessarily correctable to increase their productive capacity, with the incorporation of amendments of chemical and organic substances.

On the other hand, Black, (1975), determines that in alkaline soils, plants do not thrive easily, because high alkaline levels plants do not thrive easily in alkaline soils, because the high concentrations of hydroxide ions have direct detrimental effects on plants. These effects occur between a pH of 8.5 and 8.5, as Jones found in 1961, because the toxicity of hydroxide ions to plants 1961, because the toxicity of aluminium to cultivated plants is strong. In sodic and non-saline soils saline soils, there are differences in elements such as phosphorus, iron, zinc, which have a low solubility in alkaline conditions. solubility in alkaline conditions, the difference is combated to lower the pH and reduce the presence of salts. presence of salts.

Likewise, the author Pizarro (1987) considers that soils containing sufficient proportions of absorbed sodium and high PSI values cause the dispersion of colloids, the consequence of which is the loss of soil structure, whereas the salt content in sodic soils is low and the electrical conductivity (EC) is less than 2 mmhos/cm and the reaction of this soil varies according to the amount of exchangeable sodium (PSI), and also due to the presence of CO_3 or CO_3HO the pH ranges between 8 and 9. Dissolved salts in soils are found in small quantities, such as chloride, sulphates, bicarbonates, although there may be small concentrations of sodium and bicarbonates. This author classifies soils according to the percentage of exchangeable sodium (Na) as shown in the table.

Categoría	Porcentaje de sodio intercambiable (PSI)
Ligeramente sodico	7 - 15
Medianamente sodico	15 - 20
Fuertemente sodico	20 - 30
Extremadamente sodico	>30

Table 4 Classification of Sodic Soils

The author Aidarov (1985) mentions that sodic soils (solonetz) are characterised by their exchangeable sodium content. characterised by their exchangeable sodium content, the soil horizons are affected by the alkaline reaction, such as sodium, calcium, potassium and magnesium carbonates. alkaline reaction, such as sodium, calcium, potassium and magnesium carbonates. presence of salts, the soil's capacity is degraded, but it occurs more frequently in arid regions.

Regions, at the same time it becomes compacted and therefore has a low permeability and a poor moisture reserve for the plants. for the plants.

Effect of saline soils on plants

The researcher Gaetz (1997) points out that the influence of salinity causes various problems in plant development, the most important of which are:

- a) Problems in adsorption: at high concentrations of soluble salts, the plant makes a greater effort in the suction of nutrients and water.
- b) The toxicity problem it causes in plants is in the metabolic pathway, thus altering the development of the crop. It alters the development of the crop; plants that are sensitive to salinity may even die.
- c) The problem of the physical structure of the soil is caused by the dispersion of organic matter and clay adsorption, which causes low permeability, so that white crusts form on the surface of the soil.
- d) The same author mentions that the controversy between the effects caused by low soil fertility, stunted plants, which is due to low fertility and salinity, the symptoms are not so easy to detect because the characteristics are similar, perhaps it could be differentiated by the following: the stunted size, the dark green leaves, this is due to an increase in chlorophyll content, these symptoms can be clearly observed in the leaves, to determine the effect of soluble salts, therefore a series of analytical determinations must be carried out, such as chemical analysis of the plant in the laboratory.

Regarding resistance to salinity, Medina (1997) indicates that not all species are resistant to high concentrations of salts, in many cases influencing plant characteristics such as colour, size and yield, therefore the concentration of organic matter is poor, whereas the assimilation of phosphorus helps in the adsorption of nutrients to the plant.

The authors Bonh, (1993) also point out that the main effect of soluble salts is to prevent the use of nutrients and water, because the roots have a semi-permeable (weak) membrane and the osmotic function of the plant is hindered when salts are extracted, In the case of salinity-sensitive plants, this can lead to serious problems. In this way, crops can be selected according to their resistance to saline-sodic soils, as shown in the table below.

Altamente tolerante	Moderadamente tolerante	Poco tolerante
- Cebada	- Higuera	- Limonero
- Remolacha	- Olivo	- Manzano
- Algodón	- Trigo	- Peral
- Remolacha azucarera	- Sorgo	- Albacornoque
	- Arroz	- Duramo
	- Alfalfa	- Almendra
	- Tomate	- Rabano
	- Col	- Apio
	- Zanahoria	- Frijol
	- Cebolla	- Trébol blanco
	- Lechuga	- Puroto
	- Maíz	- Habas(leguminosa)
	- Patata	
	- Repollo	
	-	

Table 5 Classification of crops tolerant to saline-sodic soils

FAO (1986) also points out that most plants are sensitive to salinity, which causes serious problems in the first few weeks of growth. causes serious problems in the first few weeks of seedling development, whereby the leaves appear leaves are dusty because the soluble salts are pushed through the leaves. However, in saline soils there is a greater difficulty, as the physical, chemical and biological properties of the soil are extremely are extremely exalted, so the pH is greater than 8.5 and with low permeability with alkali black crusts, making it almost impossible to manage sodic soils.

Reclamation of saline alkaline soils

According to Colacelli (2000), the recovery of saline or alkaline soils will be carried out with the aim of recovering the productive capacity; the incorporation of mechanical actions, chemical, biological and hydrotechnical improvers, is according to the chemical and physical analysis of the soil, the substances that can be used as correctors in saline soils and alkalinity are shown in the table.

Tomando el azufre como unidad base	
Mejoradores de suelos	Equivalente en 1tn de azufre
Azufre	1tn
Yeso Agrícola	5.35 tn
Caliza molida	3.11 tn
Acido Sulfúrico	3.06 tn
Sulfato Ferroso	8.69 tn
Sulfato de Aluminio	6.94 tn
Pati sulfato de calcio	4.17 tn

Table 6 Substances to be used as correctors for soils affected by saline soils

Organic improvers that are also available in any region, such as ground seaweed, sugar foam and organic matter, are also highlighted. such as ground seaweed, sugar cane foam, organic matter.

Based on the above-mentioned premises, the following recovery methods are indicated.

a) Recovery by the physical method

Colacelli (2000) mentions several sets of well-differentiated mechanical measures, the most common of which are soil texture profile conditioning, which can be aided by deep tillage or fallow and artificial waterproofing, which aids soil aeration and decomposition.

b) Recovery by chemical method

The same author points out that the addition of chemical soil improvers provides calcium in soluble form to soils with sodium problems and lowers the pH, where NaCO_3 action occurs, which removes sodium from the soil. NaCO_3 reaction occurs, which replaces the sodium absorbed in the colloidal fraction particles. various chemical and inorganic ameliorators are now used to improve the physical condition of salt-affected soils. soils affected by salts.

On the other hand, research carried out in Guadalajara and Jalisco (2000), found that in alkaline soils there are alkaline soils abound with carbonates of sodium, magnesium, potassium, etc., which are intended to be with calcium sulphate (gypsum) and elemental sulphur, but always taking into account the chemical and physical chemical and physical conditions of the soil, as there is a risk that the calcium will precipitate.

According to producers in Mexico, calcium sulphate should be applied to soils that are affected by salts to improve their fertility and to improve crop yields; calcium sulphate improves the physical conditions of the soil and on the other hand neutralises the cation and anion elements that are abundant in alkaline-saline soils while reducing the pH.

In the same way, Zerega Adams (Fonalap- Estación Experimental Yaracuy y Yaritagua Venezuela 2001) states that the reclamation of saline and alkaline soils, generally tends to be uneconomical when the better soils are used. uneconomical when chemical improvers such as sulphuric acid, aluminium sulphate, ferrous sulphate, etc., are used. sulphate, ferrous sulphate, etc., but when organic amendments such as green manure are used, sugar cane molasses, manure or organic material are not as economical as the chemical ones, but you could say that they are economical, but it could be said that they are very slow reacting compared to chemicals.

c) Recovery by the hydrobiological method

With reference to this aspect, Colacelli (2000) mentions that there are crops that improve saline and alkaline soils, which help to improve the physical conditions of the soil, such as root crops and fodder, like atriplex, which helps to extract soluble salts, as well as favouring the absorption of organic matter and water infiltration.

On the other hand, the biology of the plant must be evaluated to be able to observe the chemical reactions caused by the amendments or improvers such as sulphur, it can be observed by means of the behaviour of the plant, for example the colour of the plant, size, etc., and perhaps a chemical analysis of the leaves can be carried out to determine the toxicity of the plant.

d) Recovery by hydro-technical method

References cited by FAO (1986), indicate that reclamation of saline soils can be done by washing or flooding with water that favours leaching of salts, but the quality of water must be taken into account, otherwise the efficient physical properties of the soil may be affected; in case it may have a higher concentration of soluble salts, it would worsen rather than improve instead of an improvement.

In alkaline soils it is recommended to use amendments before applying water, because the high concentration of sodium can precipitate in the soil, so in this case it is necessary to displace the salts, after which they can be leached out.

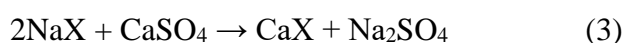
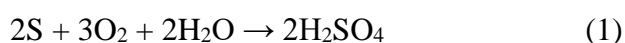
According to Cepeda Dovala (1991), the following aspects should be considered when applying water or flooding to improve the physical conditions of the soil.

- Water quality.
- Salt distribution.
- Groundwater level.
- Soil drainage conditions.

All these aspects must be taken into consideration in order not to have conflicts of worsening physical and chemical conditions of the soil, which are affected by salts. the physical and chemical conditions of the soil, which are affected by salts; moreover, when it comes to research, many precautions must be taken. research, many precautions have to be taken.

Chemical and biological reaction of sodic saline soils

According to Bohn. (1993), soils affected by salts can be improved in their physical properties with improvers such as gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) with several kg/ha, e.g., at a rate of 1000 kg/ha. these soils require an increase in calcium, to replace the exchangeable sodium; among these, gypsum is also considered as a soil improver. is also considered as the elemental sulphur improver, of course, this element reacts to form sulphuric acid. reacts to form sulphuric acid by means of oxidation by soil microorganisms; for reference, an evaluation should be carried out each year to reference, an evaluation should be carried out every 2 to 3 years to know if another application of improvers is necessary. application of improvers is necessary; in this respect, the following reactions are explained:



According to Medina (1993), the correction of alkaline soils that can be carried out with elemental sulphur to reduce the pH from 8 to 7.5, acidifying products must be used, the most economical of which is gypsum (SO_2SO_4). the most economical being gypsum (SO_4Ca), then water must be applied (washing) to leach the sodium from the soil. to leach the exchangeable sodium, for each calcium ion (Ca^+) supplied, which is demonstrated in the following way as follows: SO_4Ca (contributed) + 2Na + complex $\rightarrow \text{SO}_4\text{Na}_2$ (leached) + Ca + (passes to the complex).

Na_2SO_4 is then removed by leaching, thus gradually decreasing the sodium (Na^+). sodium (Na^+) in the soil progressively decreases, while calcium increases due to the reduction of alkalinity-salinity and therefore the pH of the soil decreases.

Wihttig and Janitzky (1968), carried out an investigation on the recovery of soils affected by salts with the use of chemical improvers, observed the microbial activity or chemical reaction of the bicarbonates of calcium, magnesium, etc., which are precipitated in the soil, indicating that calcium is provided to replace the exchangeable sodium by means of the following reactions.

Saline-sodic soil

Solution $\text{Na}^{++} > \text{Ca} + \text{Mg}$; $\text{SO}_4 > \text{Cl} > \text{HCO}_3$
High exchangeable Na^{++} , precipitated carbonate of Ca^{++} and Mg^{++}

Organic amendment (RC or OH) (microbial activity, CO_2 production) $2\text{CO}_2 + 2\text{H}_2\text{O} + \text{CaCO}_3 + \text{MgCO}_3 \rightarrow \text{Ca} (\text{HCO}_3)^2 + \text{Mg} (\text{HCO}_3)_2$ Exchangeable Na^{++} $\text{Ca} (\text{HCO}_3)^2 + \text{Mg} (\text{HCO}_3)^2 \rightarrow \text{Ca}^{++}$ Exchangeable Mg^{++} $\text{Mg}^{++} + 4\text{NaH}_3$

Collision of good drainage leachate (removal of NaHCO_3 and Na_2SO_4 in drainage water).

Normal soil

Table 7

However, water must be added to remove NaHCO_3 in order to avoid capillary access to the soil surface.

Capillary access to the soil surface, so with the practice of amendments it is possible to improve the physical properties affected by salts. physical properties affected by salts.

Results and discussion

Results obtained

PH

The data in the table show the favourable response according to the needs of the plant. Needs of the plant. The pH obtained with the treatments are optimal for the species grown in the area.

pH-H2O			
testigo	1300 kg/ha	1500 kg/ha	1700 kg/ha
8.4	7.5	7.42	7.31

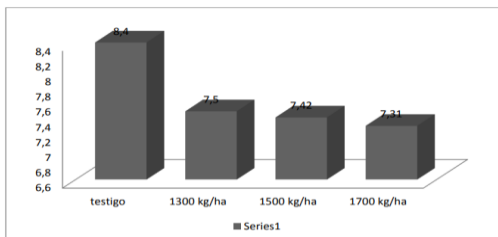


Table 8

Electrical conductivity

The values obtained with the applied amendments result in a decrease in conductivity, this parameter is clearly a function of the soluble salts present in the soil.

conductividad dS/m					
testigo	1300 kg/ha	testigo	1500 kg/ha	testigo	1700 kg/ha
1.042	0.83	1.042	0.58	1.042	0.96

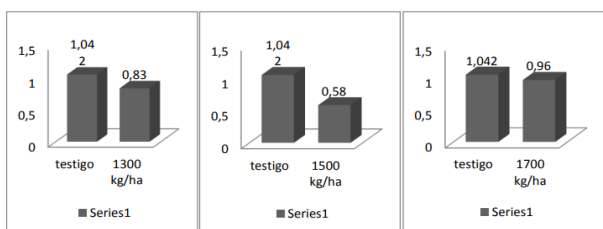


Table 9

Total Nitrogen

Nitrogen as an organic form is used by plants. Nitrogen is part of the soil organic matter and as such contributes favourable nutrients to the soil.

Nitrogeno Total %					
testigo	1300 kg/ha	testigo	1500 kg/ha	testigo	1700 kg/ha
0.151	0.12	0.151	0.12	0.151	0.14

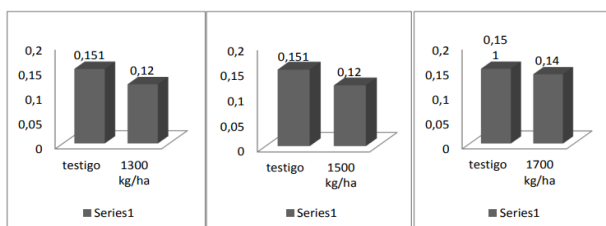


Table 10

Assimilable phosphorus

The substantial increase in phosphorus, a parameter that helps the roots and the plant to develop faster, improving water use efficiency and accelerating ripening.

Fosforo Asimilable mg P/kg					
testigo	1300 kg/ha	testigo	1500 kg/ha	testigo	1700 kg/ha
1.83	4.49	1.83	1.41	1.83	7.14

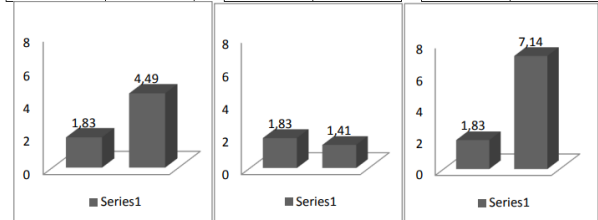


Table 11

Calcium

The calcium surplus obtained from the treatment is very favourable for a fertile soil because the plants will have more ionic Ca⁺⁺ to absorb. The main source of calcium is the main source of ionic calcium.

calcio meq/100g					
testigo	1300 kg/ha	testigo	1500 kg/ha	testigo	1700 kg/ha
9.06	25.3	9.06	19.8	9.06	23.8

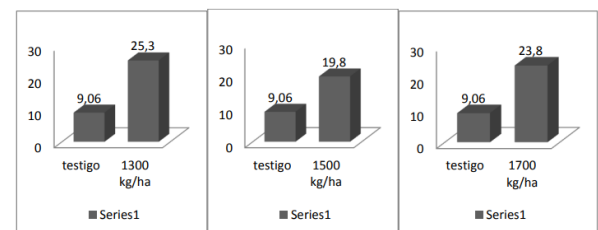


Table 12

Magnesium

The absence of this element is more common than that of calcium. Ionic magnesium is absorbed by plants, but magnesium is generally present as a compound that cannot be.

magnesio meq/100g					
testigo	1300 kg/ha	testigo	1500 kg/ha	testigo	1700 kg/ha
2.97	3.74	2.97	3.71	2.97	3.74

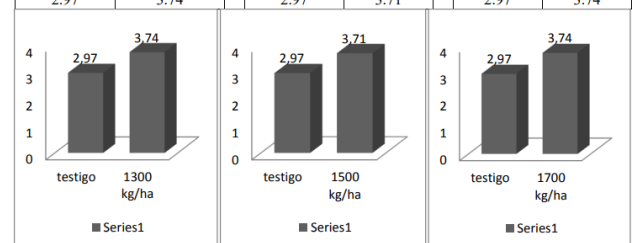


Table 13

Sodium

The decrease of sodium indicates the reduction of salinity in the soil since it is the precursor element of salinity. Due to the presence of calcium and sulphur, sodium ions are difficult for the plant to assimilate.

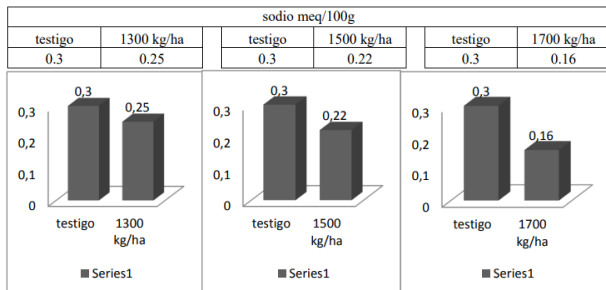


Table 14

Potassium

Potassium as an ion is an element that contributes physiologically and nutritionally to the plant. Available potassium remained moderately constant, since potassium was present as feldspars and potassium ions were produced with the application of the treatment.

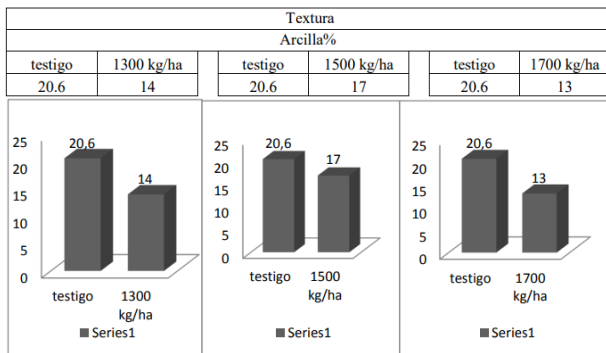


Table 15

Texture

A soil with greater availability to the plants was obtained in parameters such as porosity, saturation that the soil could have, thus obtaining greater soil moisture retention.

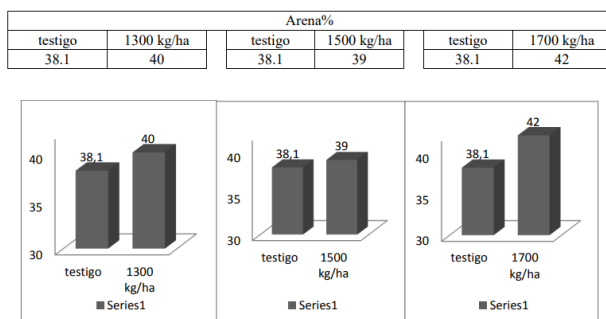


Table 16

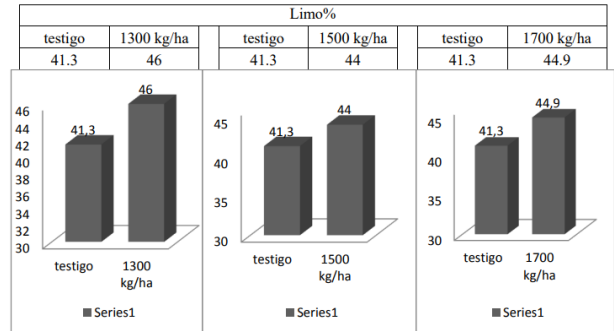


Table 17

Discussion

The results of the variation of the exchangeable bases in the soil by the effect of the application of calcium sulphate to a saline soil with a pH of 8.4 showed a decrease in pH to 7.31, 7.42 and 7.5 in its three levels; the repercussion is shown in the increase in some parameters and the decrease in others.

In the case of calcium, this increased to 131% with the application of 1700 kg/ha of calcium sulphate, 109% with the 1500 kg/ha treatment and 139% with 1300 kg/ha.

As Almaraz (1998) points out, this phenomenon was since thanks to the application of calcium sulphate in the soil, the calcium sulphate in the soil increased and so did the calcium radicals, which are the ones that displace the sodium that causes salinity.

As for magnesium, it was determined that before the application the amount of magnesium was 2.97 meq/100g. 2.97 meq/100g of soil, increasing from 62% in the 1500 kg/ha treatment to 63% with 1700 kg/ha. to 63% at 1700 kg/ha.

According to Cochrane (1971), this increase is due to the increase of calcium in the soil; while the amount of magnesium increases, the ions are not fixed to the soil colloids; but when calcium is present in quantities greater than magnesium, as occurred in this research, it causes this element to be absorbed by the clays and assimilated by the plants.

Although before the application of the soil amendment, the potassium content was 0.30 meq/100g of potassium, the effect of the treatments decreased from 76% with the 1300 kg/ha treatment to 90% with 1700 kg/ha. with 1700 kg/ha.

The explanation for this behaviour was due to the fact that the potassium, which was in the form of feldspar that is poorly assimilated for adsorption by the roots, reacted with the sulfuric acid, releasing a greater amount of potassium ions that are easily used by the roots (Bohn, 1993), which would lead one to think that the observed decrease was due to the fact that this element was consumed by the plant and leached by water. Phosphorus records showed a controversial behaviour, increasing from 145% to 290% in the three levels.

Almaraz (1998), points out that phosphorus is found in the soil in the form of a very poorly soluble compound, forming phosphates that are difficult for the plant to access; the incorporation of organic or mineral amendments such as calcium sulfate makes the reaction with the sulfuric acid formed by the calcium sulfate more soluble and helps the roots and the plant to develop more rapidly. In addition, phosphorus in its new state improves water use efficiency, accelerates ripening and is vital in seed formation.

The sodium element, considered as the precursor element of salinity, underwent a decrease from 0.3 meq/100g to 0.25 meq/100g with 1300 kg/ha, 0.22 meq/100g with a 1500 kg/ha treatment and 0.16 meq/100g with 1700 kg/ha. This decrease has made elements necessary for plant growth more available to plants because, according to Richards (1980), high concentrations of sodium in the soil hinder the adsorption of calcium, magnesium and potassium to the plants, thus atrophying soil physics.

Because of all these reactions and variations, a reduction in soil salinity was manifested, favoring soil nutrients. of soil salinity, favoring soil nutrients; the reduction of sodium manifested a greater growth of established plants (Bohn 1993; Buckman and Grady, 1993; Black 1975). growth of established plants (Bohn 1993; Buckman and Grady, 1993; Black 1975).

As a result of the decrease in sodium and potassium in the soil, in addition to the increase in calcium, magnesium and phosphorus, the effective cation exchange capacity also underwent a variation, being lower because of the three treatments compared to the initial soil values.

An economic analysis showed that an optimum application for alkali soil improver is 1300 kg/ha.

Conclusions

Having obtained positive responses from each experimental unit, the proposed objectives of the research were achieved, thus leading to the following conclusions:

- Through the interpretation of the water analyses we were able to classify the irrigation water, from Yotala, as water of medium salinity (C₂) which can be used as long as there is a moderate degree of washing. In almost all cases and without the need for special salinity control practices, moderately salt tolerant plants can be produced.
- Also, irrigation water is a low sodium (S₁) water which can be used for irrigation in most soils with little likelihood of reaching dangerous levels of exchangeable sodium. However, sensitive crops, such as some fruit and avocado trees, can accumulate harmful amounts of sodium. By obtaining a pH of 7.5 we can say that our sample has a slightly basic character, although based on the reference values (6.0-9.0) it is in the common range for irrigation water. Having performed the interpretation of the water, we can say that the irrigation water used in Yotala is optimal for irrigation and that it does not cause the accumulation of soluble salts in the soil.
- The application of calcium sulphate to the soil resulted in a reduction of toxic elements for plants such as sodium and potassium; however, other elements such as phosphorus and calcium, which are beneficial as nutrients, increased. Due to the application of the treatment, a reduction in the number of soluble salts in the soil was obtained. In addition, the pH was reduced from 8.4 (strongly alkaline) to 7.4 (weakly alkaline).

- The cost of the improver (gypsum), is much lower compared to the price of other improvers such as urea, sulfur, sulfuric acid, ferrous sulfate, aluminum sulfate or limestone, therefore, it becomes much more economically therefore becomes much more economically profitable, even more so when we are talking about an area populated by retail farmers who do not area populated with retail farmers who do not have the necessary resources to apply high-priced improvers. high priced improvers.

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Stress concentration in a plate with two centered holes subjected to axial loading

Concentración de esfuerzos en una placa con dos barrenos centrados sometida a carga axial

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DOI: 10.35429/JCE.2021.13.5.31.44

Received 25 January, 2021; Accepted 30 June, 2021

Abstract

In the present work the stress concentration in a flat plate subjected to axial load is analyzed. To carry out this analysis, the stress concentration factor is determined with the help of the Ansys software, which uses the finite element theory to carry out its analyses. A total of 125 simulations are performed, obtaining the maximum stresses that support the piece, which are used to determine the stress concentration factor. Stress concentration factors are plotted as a function of S/D (hole center distance/hole diameter) for W/D (part thickness/hole diameter) ratios of 1.2, 1.5, 2, 2.5, 3. The graphed results are regressed using the method of least squares to obtain equations that can be used to predict the stress concentration factor of this type of mechanical parts. The equations obtained are sets of linear, exponential, and polynomial equations with correlation coefficient values that vary from 0.8835 to 0.9997.

Resumen

En el presente trabajo se analiza la concentración de tensiones en una placa plana sometida a una carga axial. Para realizar este análisis se determina el factor de concentración de tensiones con la ayuda del software Ansys, que utiliza la teoría de elementos finitos para realizar sus análisis. Se realizan un total de 125 simulaciones, obteniendo las tensiones máximas que soporta la pieza, que se utilizan para determinar el factor de concentración de tensiones. Los factores de concentración de tensiones se grafican en función de S/D (distancia entre centros de agujeros/diámetro de agujeros) para relaciones W/D (espesor de la pieza/diámetro de agujeros) de 1.2, 1.5, 2, 2.5, 3. Los resultados graficados se regresan utilizando el método de los mínimos cuadrados para obtener ecuaciones que puedan ser utilizadas para predecir el factor de concentración de tensiones de este tipo de piezas mecánicas. Las ecuaciones obtenidas son conjuntos de ecuaciones lineales, exponenciales y polinómicas con valores de coeficientes de correlación que varían entre 0,8835 y 0,9997.

Concentration, Efforts, Factor

Concentración, Esfuerzos, Factor

Citation: ORTEGA, Francisco, PALACIOS, Francisco, GARCIA, Diego and GARCIA, José. Stress concentration in a plate with two centered holes subjected to axial loading. *Journal Civil Engineering*. 2021. 5-13:31-44.

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Nomenclature

The nomenclature used during the development of this work is shown below.

TO	Cross-sectional area of the plate
B	Deformation matrix
D	Hole diameter
F	Force applied to part
$H_{1,2}$	Quadrature Weight Coefficients gaussian
J	Jack o bianco
K and K_{you}	stiffness matrix
K_{you}	Fact stress concentration tower
L	Plate length
N	Matrix of form functions
$N_{i...p}$	Fan form of node i, j, k, l, m, n, o, p belonging to the square element
R^{two}	Correlation coefficient
s	Separation between the centers of the drill holes
W	Plate width
x	Element global coordinate
Y	Element global coordinate
η	Local coordinate of the element
ξ	Local coordinate of the element
σ_{max}	Maximum effort
$\sigma_{theoreti}$	Theoretical effort

Introduction

The stress concentration is one of the main problems that designers must worry about when designing any type of machinery or equipment, because stress concentrations can cause the different mechanical parts to fracture and the machine or equipment to lose its operating conditions. For this reason, designers should try to eliminate stress concentrators in mechanical parts as much as possible.

Special attention must be paid to analyze the stress concentrators in the best possible way so that the designs that are made work properly and are as reliable as possible.

Many researchers have studied different types of stress concentrators and the effect they have on different materials. Zheng & Niemi (1997) investigates the relationship between stress and local strain, as well as the nominal stress proposed by Moski and Glinka.

The authors comment that said stress is good for low stress amplitudes, however both the Neuber rule and the Moski and Glinka methods do not produce good results for large stress amplitudes. For their part, Roldan & Bastidas (2002) present a study which analyzes the stress concentration on a flat plate of constant thickness subjected to stress at its ends, making a comparison of the results obtained through the theory of elasticity, experimentally and by the finite element method.

Maíz, Rossi, Laura & Bambill (2004) comment that the normal stresses increase in absolute value with the size of the hole for all orthotropic materials. For their part, Bambill, Susca, Laura & Maíz (2005) mention that the stresses generated in the environment of a circular hole of an orthotropic plate when it is subjected to hydrostatic stresses in a plane, are strongly affected by the elastic characteristics of the material. of the plate under consideration.

In a flat plate with two holes loaded at its ends, the stress concentration interaction depends on the distance and the size ratio between them (Monroy & Godoy, 2006). Martínez, Carrera & Ferrer (2006) presents the study of a flat plate with a hole in the center, under the effects of a linear load gradient, they establish an approximate computational model that reduces the type of load required and supports the results obtained experimentally. by photoelasticity and numerically by using the software ANSYS®.

Noda & Takase (2006) analyze the stress concentration in a round bar with a circular arc or V-shaped notch that supports torsion, tension and bending loads, obtaining equations that allow determining the stress concentration in these pieces with an error of less than 1%. Susca, Bambill, Laura & Rossi (2006) analyze the stress concentration generated by a small rectangular hole with rounded edges in an orthotropic plate, observing that the greatest stress concentration factors are found in the main axis 1 which is at an angle of 67.5° with respect to the x-axis.

The theoretical stress concentration factor for parts made of orthotropic materials is significantly influenced by the type of applied load, as well as by known parameters such as the relative size of the hole.

In addition, the load that produces the greatest effects on the theoretical factors of stress concentration is the biaxial tension-tension load, whose effects are not very noticeable (Méndez & Torres, 2006). For his part, Sánchez (2006) analyzes the stress concentration in an orthotropic plate with an elliptical opening subjected to an axial load for a bone material taken from the diaphysis of the human tibia.

The reason for analyzing the elliptical opening and not the circular one is because the elliptical opening leads to a generalized analysis and in the limit, when the ratio of the semi-minor axis to the semi-major axis of the ellipse is very large, the hole tends to be a very large slot. thin (crack) and therefore its stress concentrator increases. The stress concentration factor in composite materials depends closely on the geometry of the piece, in addition to the fact that the stress concentration factor is not a sufficient value, by itself, for the prediction of failure in laminated materials (Domínguez, Santos, Robles & Ortega, 2006).

It is difficult to establish behavior parameters in orthotropic materials, but there is a marked influence between the relationships of the elastic constants and the stress concentration factors (Susca, Bambill & Rossit, 2007). Peñaranda, Pedroza & Méndez (2007) analyze the stress concentration in a plate of infinite length with two holes of equal radii, using finite element software, varying the distance between the centers of the two holes and their diameter. For their part, Gómez, Elices, Berto & Lazzarin (2008) study the stress concentration factor for U-shaped notches which support mixed loads using the concept based on the criterion of the average deformation of the energy density.

Sonmez (2009) carried out a study to optimize the shape of the fillets and reduce the stress concentration in flat and round bars subjected to axial loads, bending, torsion or combined loads. While Osorio, Rodríguez, Gámez & Ojeda (2010) studies the distribution of stresses produced by the effect of various loading conditions, in said study a numerical evaluation is carried out to analyze a plate for internal fixation of fractures occurring in the distal radius, the results show a concentration of stresses in the regions adjacent to the plate holes and in the screws located at the ends of the fixation plate.

Balankin, Susarrey, Mora Santos, Patiño, Yoguez, & García (2011) theoretically and experimentally study the effect of long-range correlations in the material microstructure on the stress concentration in the vicinity of the notch tip. According to the results obtained in experimental tests that they carry out, they obtain a good approximation of the effect of the size of the notch on the resistance to fracture of sheets of different types of paper.

Louhghalam, Igusa, Park, Choi & Kim (2011) present a model that is numerically coupled to the finite element method to determine the stresses at the corners of rectangular openings in plates subjected to bending. On the other hand, Sharma, Panchal & Patel (2011) analyze an infinite orthotropic plate with a circular hole subjected to internal pressure using the Mushkhelishvili method, finding that the orientation of the fibers and the stacking sequence have a significant effect on the distribution. stress around the hole.

While Sharma (2011) determines the stress concentration using Mushkhelishvili's method around circular, elliptical and triangular cutouts in infinite plates of laminated composite materials supporting arbitrary biaxial loads.

The stress concentration is one of the factors that contribute to reducing the life of a mechanical component subjected to fatigue (Khalil Abada, Pasinia & Cecereb, 2012). Dharmin, Khushbu & Chetan (2012) present a review of the research that has been carried out about stress analysis on infinite plates with cutouts. Many analytical, numerical, and experimental techniques are available to reduce the stress concentration factor around discontinuities. Different ways to determine the stress concentration factor in flat plates composed of different materials under different loading conditions have been reported (Nagpal, Jain & Sanyal, 2012).

In general, the maximum stress concentration for plates of finite width with a central hole under static axial load always occurs at the periphery of the hole, in addition, the stress concentration factor is maximum at the tip of the hole, that is, perpendicular to the load (Nagpal, Sanyal & Jain, 2013). Mohan Kumar, Rajest, Yogesh & Yeshaswini (2013) analyze the stress concentration in flat plates with circular, triangular, and rectangular holes, studying the variation of the stress concentration due to the hole geometry change. For their part, Henrique, Tácito & Moreno (2013) perform a finite element analysis to predict the elasto-plastic stress concentration factor for a 1020 steel alloy.

The use of modified elliptical shaped notches is suggested because it causes a lower stress concentration compared to semicircular notches and slots, the ratio of the minor and major axes of the ellipse should be between 0.3 and 0.4 (Ahsan, Prachurja, Ali & Mamun, 2013). On the other hand, Momcilovic, Motok & Maneski (2013) carry out an analysis of the stress concentration factor in the corner of an opening in a rectangular plate with small radii of curvature, using analytical, experimental, and finite element methods, making a comparison among the three methods.

Ortega, Garcia, Rocha & Guzmán (2013) show how to obtain stress concentration curves with the help of ANSYS® software. The determined stress concentration factors are plotted in a dimensionless way, obtaining stress concentrator curves.

The least squares method is used to fit the data from these curves to sixth degree polynomial equations with a value of R^2 between 0.9987 and 1.

Darwisha, Tashtoushb & Gharaibehb (2013) study the in-plane stress concentration factor (SCF) in countersunk rivet holes in orthotropic rolled plates under uniaxial tensile loading. Finite element analysis is performed using ANSYS® software. The effect of various geometric and material parameters such as plate thickness, straight shank radius, countersink angle, countersink depth, plate width, and layer angles of SCF laminate are investigated.

Based on the results, it was found that the SCF values obtained by means of the formulated equation are within 7% of the finite element (FE) results for 96% of the runs and that the maximum overall error is less than 14%.

Ou, Lu, Cui & Lin (2013) show a shape optimization approach to minimize stress concentration and peaks caused by contact pressure. Their approach focuses on directly modifying the shape of the layers near the region where the stress concentration is measured by the Von Mises stresses and the contact surface measures the contact pressure. To evaluate the proposed approach, three case studies are presented, the results obtained show that the optimization of developed form is especially applicable to the design and analysis of multi-body systems where the limit stress concentration and contact pressure distribution are an important consideration.

Liu & Tang (2015) present a detailed analysis on stress concentration in composite materials reinforced with unidirectional notched fibers. Due to the formation of longitudinal splitting at the notch tips along the fiber direction, the extremely high stress concentrations ahead of the notch tip could be drastically reduced for composite materials under remote stress. The inability of the widely used material property degradation method to accurately redistribute local stresses at notch tips is examined.

The objective of this work is to analyze the stress concentration in a flat plate with two centered holes and subjected to an axial tension load.

A total of 125 simulations are carried out in a finite element software in order to find the maximum stress that the plate supports and subsequently determine the stress concentration factor, the results obtained are plotted for the W/D ratios of 1.2, 1.5, 2, 2.5 and 3 depending on the s/D ratio, finally the least squares method is applied to the values obtained to obtain equations that allow predicting the stress concentration factor for the analyzed case study.

All finite element

There are many facets of engineering in which it is necessary to determine the distribution of stresses and strains in an elastic continuum (Zienkiewicz, 1982). It is generally accepted that numerical analysis methods in engineering and applied sciences fall into three broad categories: finite differences, finite elements, and boundary elements (Cerrolaza, 2006).

Finite Element Analysis (FEA) has had a tremendous boost since the advent of the computer age. This has allowed the creation of multiple platforms to implement the theory of finite elements, of which Ansys is a particular example (Roa Garzón & Garzón Alvarado, 2002).

The finite element is a numerical method that is used for the modeling and simulation of problems in many fields of engineering, such as: structural analysis, heat transfer, fluid mechanics, electricity and magnetism, or a combination of them.

The term "finite element" expresses the idea that the object of study can be divided into a certain number of elements, with a defined mathematical model that can be represented in a matrix arrangement whose solution is obtained by applying the basic rules of linear algebra through of a computer program (Córdova Aquino & De Dios Domínguez, 2007)

There are two general approaches associated with the understanding and application of the finite element method. The first approach is called the force or flexibility method, which is based on the use of internal forces as the unknowns of the problem. To obtain the governing equations, the equilibrium equations have to be used first. Then it is necessary to introduce additional equations generated by the compatibility equations. The result is the array of redundant algebraic equations that determine the unknown internal forces. The second approach of the method is the displacement method, or stiffness method, which assumes the displacement of nodes as the unknowns of the problem (Pérez Mitre, 2004).

Fonseca Lopes (2011) mentions that regardless of the physical nature of the problem, its analysis using the Finite Element Method follows the following steps:

- Definition of the problem and its domain.
- Discretization of the domain.
- Identification of the state variable(s).
- Formulation of the problem.
- Establishment of reference systems.
- Construction of the functions of approximation of the elements.
- Determination of the equations at the level of each element.
- Transformation of coordinates.
- Assembling the equations of the elements.
- Introduction of the boundary conditions.
- Solution of the resulting set of simultaneous equations.
- Interpretation of the results.

In the present work, an eight-node quadrilateral element is used to perform the analysis in ANSYS®. Figure 1 shows a schematic of the eight-node quadrilateral element.

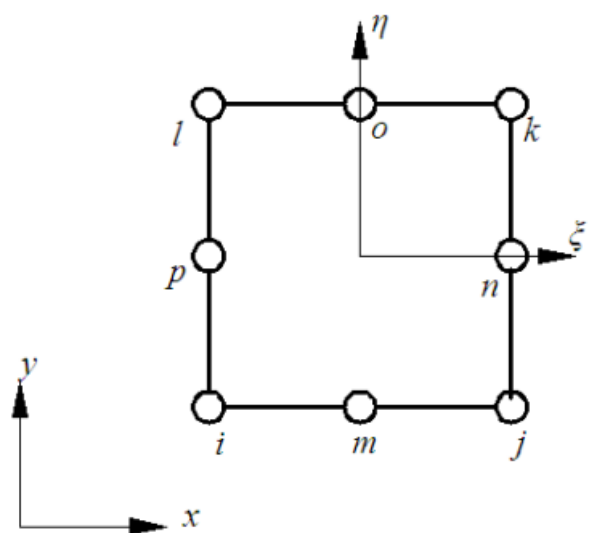


Figure 1 Schematic of the 8-node quadrilateral element

Equations (1) through (8) are the shape functions of the nodes of the element in Figure 1 in terms of the local coordinates.

$$N_i = \frac{1}{4}(1-\xi)(1-\eta)(-\xi-\eta-1) \quad (1)$$

$$N_j = \frac{1}{4}(1+\xi)(1-\eta)(\xi-\eta-1) \quad (2)$$

$$N_k = \frac{1}{4}(1+\xi)(1+\eta)(\xi+\eta-1) \quad (3)$$

$$N_l = \frac{1}{4}(1-\xi)(1+\eta)(-\xi+\eta-1) \quad (4)$$

$$N_m = \frac{1}{2}(1-\xi^2)(1-\eta) \quad (5)$$

$$N_n = \frac{1}{2}(1+\xi)(1-\eta^2) \quad (6)$$

$$N_o = \frac{1}{2}(1-\xi^2)(1+\eta) \quad (7)$$

$$N_p = \frac{1}{2}(1-\xi)(1-\eta^2) \quad (8)$$

The partial derivatives of the global coordinates in terms of the local coordinates are presented in Equations (9) through (12).

$$\begin{aligned} \frac{\partial x}{\partial \xi} = & \frac{\partial N_i}{\partial \xi} x_i + \frac{\partial N_j}{\partial \xi} x_j + \frac{\partial N_k}{\partial \xi} x_k + \frac{\partial N_l}{\partial \xi} x_l + \\ & + \frac{\partial N_m}{\partial \xi} x_m + \frac{\partial N_n}{\partial \xi} x_n + \frac{\partial N_o}{\partial \xi} x_o + \frac{\partial N_p}{\partial \xi} x_p \end{aligned} \quad (9)$$

$$\begin{aligned} \frac{\partial x}{\partial \eta} = & \frac{\partial N_i}{\partial \eta} x_i + \frac{\partial N_j}{\partial \eta} x_j + \frac{\partial N_k}{\partial \eta} x_k + \frac{\partial N_l}{\partial \eta} x_l + \\ & + \frac{\partial N_m}{\partial \eta} x_m + \frac{\partial N_n}{\partial \eta} x_n + \frac{\partial N_o}{\partial \eta} x_o + \frac{\partial N_p}{\partial \eta} x_p \end{aligned} \quad (10)$$

$$\begin{aligned} \frac{\partial y}{\partial \xi} = & \frac{\partial N_i}{\partial \xi} y_i + \frac{\partial N_j}{\partial \xi} y_j + \frac{\partial N_k}{\partial \xi} y_k + \frac{\partial N_l}{\partial \xi} y_l + \\ & + \frac{\partial N_m}{\partial \xi} y_m + \frac{\partial N_n}{\partial \xi} y_n + \frac{\partial N_o}{\partial \xi} y_o + \frac{\partial N_p}{\partial \xi} y_p \end{aligned} \quad (11)$$

$$\begin{aligned} \frac{\partial y}{\partial \eta} = & \frac{\partial N_i}{\partial \eta} y_i + \frac{\partial N_j}{\partial \eta} y_j + \frac{\partial N_k}{\partial \eta} y_k + \frac{\partial N_l}{\partial \eta} y_l + \\ & + \frac{\partial N_m}{\partial \eta} y_m + \frac{\partial N_n}{\partial \eta} y_n + \frac{\partial N_o}{\partial \eta} y_o + \frac{\partial N_p}{\partial \eta} y_p \end{aligned} \quad (12)$$

The partial derivatives of the shape functions (Equations 1 to 8) with respect to the local coordinates are presented in Equations (13) to (28).

$$\frac{\partial N_i}{\partial \xi} = -\frac{1}{4}(1-\eta)(2\xi-\eta) \quad (13)$$

$$\frac{\partial N_i}{\partial \eta} = -\frac{1}{4}(1-\xi)(-2\eta-\xi) \quad (14)$$

$$\frac{\partial N_j}{\partial \xi} = \frac{1}{4}(1-\eta)(2\xi-\eta) \quad (15)$$

$$\frac{\partial N_j}{\partial \eta} = -\frac{1}{4}(1+\xi)(\xi-2\eta) \quad (16)$$

$$\frac{\partial N_k}{\partial \xi} = \frac{1}{4}(1+\eta)(2\xi+\eta) \quad (17)$$

$$\frac{\partial N_k}{\partial \eta} = \frac{1}{4}(1+\xi)(2\eta+\xi) \quad (18)$$

$$\frac{\partial N_l}{\partial \xi} = -\frac{1}{4}(1+\eta)(\eta-2\xi) \quad (19)$$

$$\frac{\partial N_l}{\partial \eta} = \frac{1}{4}(1-\xi)(2\eta-\xi) \quad (20)$$

$$\frac{\partial N_m}{\partial \xi} = -(1-\eta)\xi \quad (21)$$

$$\frac{\partial N_m}{\partial \eta} = -\frac{1}{4}(1-\xi^2) \quad (22)$$

$$\frac{\partial N_n}{\partial \xi} = \frac{1}{2}(1-\eta^2) \quad (23)$$

$$\frac{\partial N_n}{\partial \eta} = -\eta(1+\xi) \quad (24)$$

$$\frac{\partial N_o}{\partial \xi} = -\xi(1+\eta) \quad (25)$$

$$\frac{\partial N_o}{\partial \eta} = \frac{1}{2}(1-\xi^2) \quad (26)$$

$$\frac{\partial N_p}{\partial \xi} = -\frac{1}{2}(1-\eta^2) \quad (27)$$

$$\frac{\partial N_p}{\partial \eta} = -\eta(1-\xi) \quad (28)$$

Equations (29) and (30) are the partial derivatives of the shape functions with respect to the global coordinates.

$$\frac{\partial N_{i...p}}{\partial x} = \frac{1}{|J|} \left(\frac{\partial y}{\partial \eta} \frac{\partial N_{i...p}}{\partial \xi} - \frac{\partial y}{\partial \xi} \frac{\partial N_{i...p}}{\partial \eta} \right) \quad (29)$$

$$\frac{\partial N_{i...p}}{\partial y} = \frac{1}{|J|} \left(-\frac{\partial x}{\partial \eta} \frac{\partial N_{i...p}}{\partial \xi} + \frac{\partial x}{\partial \xi} \frac{\partial N_{i...p}}{\partial \eta} \right) \quad (30)$$

The Jacobian J is defined by equation (31).

$$|J| = \frac{\partial x}{\partial \xi} \frac{\partial y}{\partial \eta} - \frac{\partial x}{\partial \eta} \frac{\partial y}{\partial \xi} \quad (31)$$

The deformation matrix is defined by equation (32), while the shape function matrix is defined by equation (33).

$$B = \begin{bmatrix} \frac{\partial N_i}{\partial x} & 0 & \frac{\partial N_j}{\partial x} & 0 & \dots & \frac{\partial N_p}{\partial x} & 0 \\ 0 & \frac{\partial N_i}{\partial x} & 0 & \frac{\partial N_j}{\partial x} & \dots & 0 & \frac{\partial N_p}{\partial x} \\ \frac{\partial N_i}{\partial x} & \frac{\partial N_i}{\partial x} & \frac{\partial N_j}{\partial x} & \frac{\partial N_j}{\partial x} & \dots & \frac{\partial N_p}{\partial x} & \frac{\partial N_p}{\partial x} \end{bmatrix} \quad (32)$$

$$N = \begin{bmatrix} N_i & 0 & N_j & 0 & \dots & N_p & 0 \\ 0 & N_i & 0 & N_j & \dots & 0 & N_p \end{bmatrix} \quad (33)$$

The Gauss-Legendre quadrature is used to determine the stiffness matrix. The stiffness matrix of each element is defined by Equation (34).

$$K^e = K_{11}^e + K_{12}^e + K_{21}^e + K_{22}^e \quad (34)$$

Where:

$$K_{11}^e = tH_1^2 J(\xi_1, \eta_1) B^T(\xi_1, \eta_1) DB(\xi_1, \eta_1) \quad (35)$$

$$K_{12}^e = tH_1 H_2 J(\xi_1, \eta_2) B^T(\xi_1, \eta_2) DB(\xi_1, \eta_2) \quad (36)$$

$$K_{21}^e = tH_2 H_1 J(\xi_2, \eta_1) B^T(\xi_2, \eta_1) DB(\xi_2, \eta_1) \quad (37)$$

$$K_{22}^e = tH_2^2 J(\xi_2, \eta_2) B^T(\xi_2, \eta_2) DB(\xi_2, \eta_2) \quad (38)$$

Equations (1) through (38) define a square element with eight nodes.

Stress concentration

Most real machine parts will have variable cross sections. will have varying cross sections.

For example, shafts are often staggered at different diameters to accept different diameters in order to accept bearings, gears, pulleys, etc. bearings, gears, pulleys, etc. A shaft may have slots for circular keyways, or for rings, or have for rings, or have wedges or holes for the attachment of other other parts. Bolts are bolts are threaded with heads larger than their shank. Any of these changes in the geometry of the cross-section geometry can cause localized stress concentrations (Norton, 1999).

The analysis of geometric shapes to determine to determine stress concentration factors becomes a difficult stress concentration factor becomes a difficult problem and not many solutions are found.

Most stress concentrators are determined by experimental techniques. Although the finite element method has been used, the fact that the elements are, in effect, finite, prevents finding the actual maximum stress. Generally, experimental approaches include photoelasticity, meshing methods, brittle coating methods and electrical methods with strain gauges (Budynas & Keith Nisbett, 2008). Mott (2006) mentions that stress concentration factors should always be used when analyzing elements under fatigue loading, because fatigue cracks usually initiate near points of high local tensile stress.

Methodology

The proposed case study consisted of study the stress concentration in a flat plate with two flat plate with two aligned and centered holes which supports axial load, we use the finite element software the finite element software ANSYS®, is used to study the stress concentration in a flat plate with two aligned and centered holes. software is used, in order to the modeling in this software, an eight-node square element is used the modeling in this software uses an eight-node square element, of which four nodes correspond to each corner of the quadrilateral of the quadrilateral and the other four nodes are intermediate nodes. four nodes are intermediate nodes. The most suitable element for such an analysis is therefore the Solid 8 element. analysis is therefore the Solid 8 node element 183.

This element is used because it is a quadrilateral with intermediate nodes at this element is used because it is a quadrilateral with intermediate nodes on the edges, so it tends to deform and couple easily during meshing in a curved section. This element is configured to work as a plane stress element with thickness. In the elaboration of the simulations an isotropic material is used, which is assigned the properties of low carbon steel, elastic modulus of 210 GPa, Poisson's ratio of 0.28.

The developed models support a tensile load at one end, while at the other end they are restrained in the x-direction.

Figure 2 presents the flat rectangular plate with two centered holes to be analyzed, which has the following characteristics:

- Plate length (L) of 0.3 m.
- Applied force (F) of 100 kN.
- Plate thickness of 0.01 m.

The width of the plate (W), the distance between hole centers (s) and the diameter of the holes (D) are variable and change in each analysis.

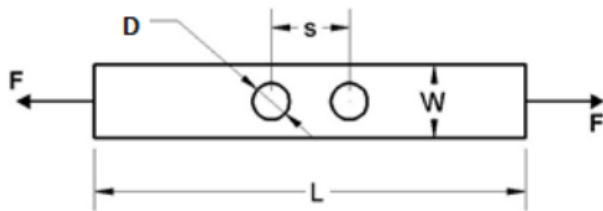


Figure 2 Flat plate with two boreholes to be analyzed

Figure 3 presents the model made in the software for the case study.

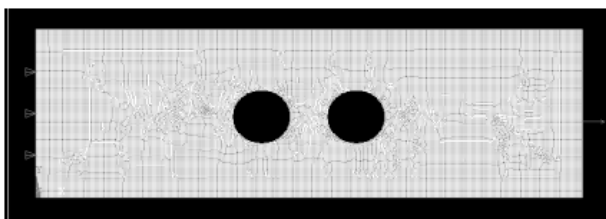


Figure 3 Model created to analyze the study case

A total of 125 simulations are performed to obtain σ_{max} and subsequently obtain the value of K_t , the simulations are distributed as follows:

- 25 simulations for the case $W/D = 3$.
- 25 simulations for the case $W/D = 2.5$.
- 25 simulations for the $W/D = 2$ case.
- 25 simulations for the case $W/D = 1.5$.
- 25 simulations for the case $W/D = 1.2$.

The simulations are performed by modifying the value of W in ranges of 0.004 m, starting at 0.096 m and ending at 0.002 m. The value of s is determined by adding the value of D to 0.02; that is, for all cases, the separation between the closest surfaces of the boreholes is assumed to be 0.02 m. The value of D is determined using Equation (39), in this equation h takes the value of 1.2, 1.5, 2, 2.5 and 3 depending on the case analyzed.

$$\frac{W}{D} = h \quad (39)$$

To obtain the value of K_t , σ_{max} is divided by $\sigma_{theoretical}$ (Equation 40).

$$K_t = \frac{\sigma_{max}}{\sigma_{teórico}} \quad (40)$$

The stress $\sigma_{theoretical}$ is obtained by means of equation (41), in this equation the value of the area is determined at the place where the cross-section of the cross-section of the part is minimum.

$$\sigma_{teórico} = \frac{F}{A} \quad (41)$$

Results

The K_t values obtained for the five W/D ratios are plotted as a function of the dimensionless S/D ratio, the graph obtained is presented in Figure 4.

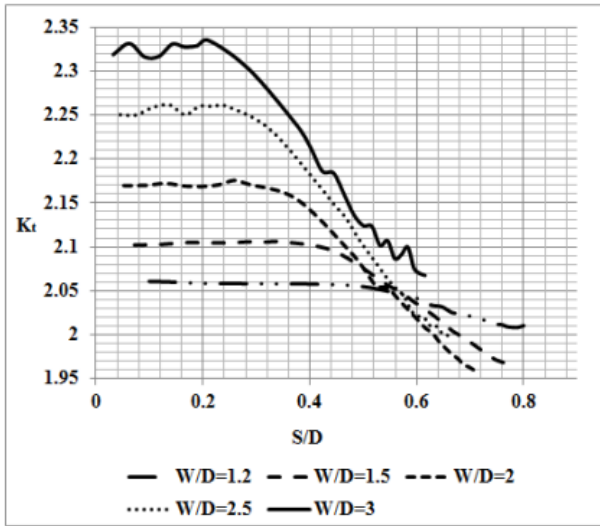


Figure 4 Stress concentration factor plot for a flat plate with two holes subjected to axial loading.

To the K_t values obtained for the W/D ratios of 1.2, 1.5, 2, 2.5 and 3 which are shown graphically in Figure 4, the least squares method is applied to obtain a set of linear equations (Equations 42 to 46), a set of exponential equations (Equations 47 to 51), a set of second-degree polynomial equations (Equations 52 to 56) and finally a set of sixth degree polynomial equations (Equations 57 to 58).

Figure 5 shows graphically the lines obtained for the linear regression using the least squares method using the least squares method and equations (42) to (46) represent the linear equations obtained for the case study analyzed.

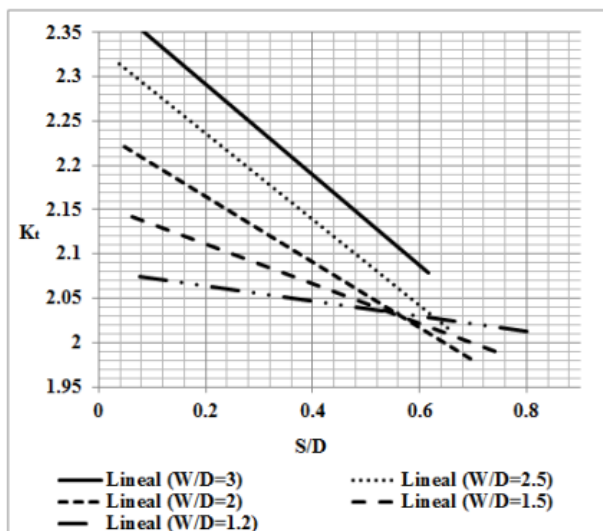


Figure 5 Linear regression plot obtained using the least squares method

Equation (42) is the linear equation for $W/D=1.2$ and has a value of $R^2 = 0.9354$.

$$K_t = -0.5136 \left(\frac{S}{D} \right) + 2.3942 \quad (42)$$

Equation (43) is the linear equation for $W/D=1.5$ and has a value of $R^2 = 0.925$.

$$K_t = -0.4846 \left(\frac{S}{D} \right) + 2.3325 \quad (43)$$

Equation (44) is the linear equation for $W/D=2$ and has a value of $R^2 = 0.9183$.

$$K_t = -0.3691 \left(\frac{S}{D} \right) + 2.2392 \quad (44)$$

Equation (45) is the linear equation for $W/D=2.5$ and has a value of $R^2 = 0.8835$.

$$K_t = -0.2241 \left(\frac{S}{D} \right) + 2.1555 \quad (45)$$

Equation (46) is the linear equation for $W/D=3$ and has a value of $R^2 = 0.8835$. for $W/D=3$ and has a value of $R^2 = 0.8884$.

$$K_t = -0.0859 \left(\frac{S}{D} \right) + 2.0813 \quad (46)$$

Figure 6 shows graphically the lines obtained for the exponential regression using the least squares method, equations (47) to (51) are the exponential equations obtained for the case study analyzed.

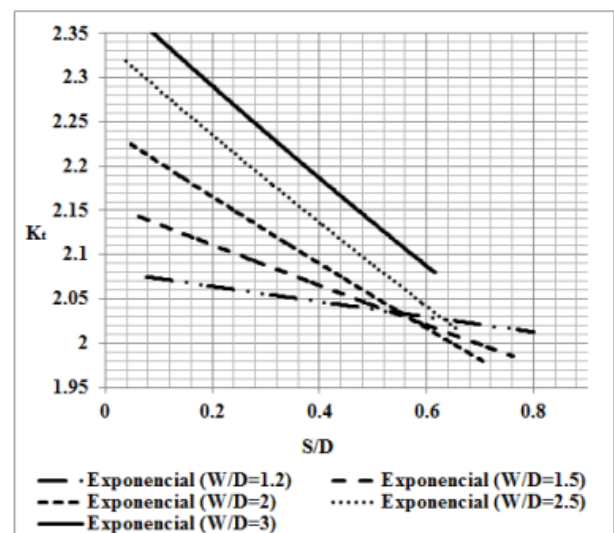


Figure 6 Exponential regression graph obtained using the least squares method

Equation (47) is the exponential equation for $W/D = 1.2$ and has a value of $R^2 = 0.9332$.

$$K_t = 2.3997e^{-0.233 \left(\frac{S}{D} \right)} \quad (47)$$

Equation (48) is the exponential equation for $W/D = 1.5$ and has a value of $R^2 = 0.9217$.

$$K_t = 2.3388e^{-0.227\left(\frac{s}{D}\right)} \quad (48)$$

Equation (49) is the exponential equation for $W/D = 2$ and has a value of $R^2 = 0.9152$.

$$K_t = 2.2439e^{-0.178\left(\frac{s}{D}\right)} \quad (49)$$

Equation (50) is the exponential equation for $W/D = 2.5$ and has a value of $R^2 = 0.881$.

$$K_t = 2.1578e^{-0.11\left(\frac{s}{D}\right)} \quad (50)$$

Equation (51) is the exponential equation for $W/D = 3$ and has a value of $R^2 = 0.8874$.

$$K_t = 2.0817e^{-0.042\left(\frac{s}{D}\right)} \quad (51)$$

Figure 7 shows graphically the lines obtained for the second-degree polynomial regression using the least squares method, equations (52) to (56) are the second-degree polynomial equations obtained for the case study analyzed.

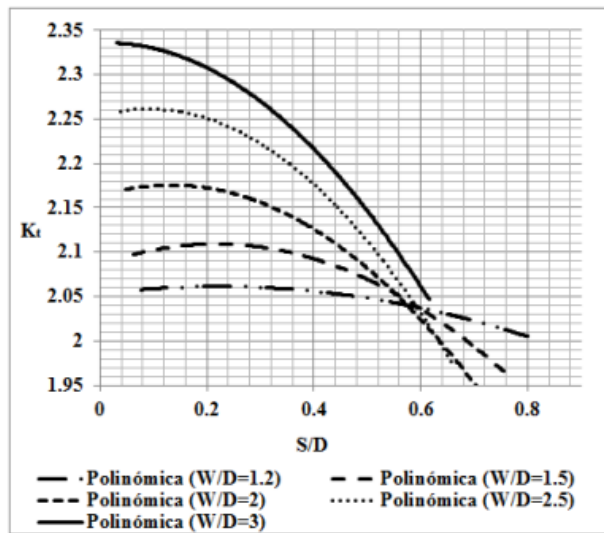


Figure 7 Plot of second-degree polynomial regression obtained by the least square's method, squares method

$$K_t = -0.7972\left(\frac{s}{D}\right)^2 + 0.0207\left(\frac{s}{D}\right) + 2.3357 \quad (52)$$

Equation (52) is the second-degree polynomial second degree polynomial equation for $W/D = 1.2$ and has a value of $R^2 = 0.9761$.

$$K_t = -0.8855\left(\frac{s}{D}\right)^2 + 0.1596\left(\frac{s}{D}\right) + 2.2542 \quad (53)$$

Equation (53) is the second degree polynomial equation for $W/D = 1.5$ and has a value of $R^2 = 0.9871$.

$$K_t = -0.6943\left(\frac{s}{D}\right)^2 + 0.1847\left(\frac{s}{D}\right) + 2.1633 \quad (54)$$

Equation (54) is the second-degree polynomial equation for $W/D = 2$ and has a value of $R^2 = 0.9918$.

$$K_t = -0.4954\left(\frac{s}{D}\right)^2 + 0.2151\left(\frac{s}{D}\right) + 2.0858 \quad (55)$$

Equation (55) is the second-degree polynomial equation for $W/D = 2.5$ and has a value of $R^2 = 0.9949$.

$$K_t = -0.1679\left(\frac{s}{D}\right)^2 + 0.0742\left(\frac{s}{D}\right) + 2.0531 \quad (56)$$

Equation (56) is the second-degree polynomial equation for $W/D = 3$ and has a value of $R^2 = 0.9842$.

Figure 8 shows graphically the lines obtained by the sixth-degree polynomial regression using the least squares method, equations (57) to (61) are the sixth degree polynomial equations obtained for the case study analyzed.

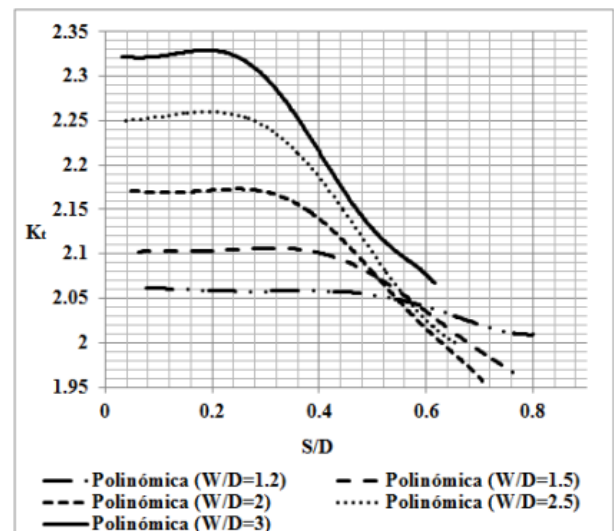


Figure 8 Sixth degree polynomial regression graph obtained by the least square's method

$$K_t = -152.39 \left(\frac{s}{D}\right)^6 + 257.58 \left(\frac{s}{D}\right)^5 - 146.04 \left(\frac{s}{D}\right)^4 + 29.371 \left(\frac{s}{D}\right)^3 - 1.5742 \left(\frac{s}{D}\right)^2 - 0.0281 \left(\frac{s}{D}\right) + 2.3236 \quad (57)$$

Equation (57) is the sixth-degree polynomial equation for $W/D = 1.2$ and has a value of $R^2 = 0.9964$.

$$K_t = -36.163 \left(\frac{s}{D}\right)^6 + 72.68 \left(\frac{s}{D}\right)^5 - 46.463 \left(\frac{s}{D}\right)^4 + 9.0564 \left(\frac{s}{D}\right)^3 - 0.4102 \left(\frac{s}{D}\right)^2 + 0.0417 \left(\frac{s}{D}\right) + 2.249 \quad (58)$$

Equation (58) is the sixth-degree polynomial equation for $W/D = 1.5$ and has a value of $R^2 = 0.9992$.

$$K_t = -58.154 \left(\frac{s}{D}\right)^6 + 124.53 \left(\frac{s}{D}\right)^5 - 95.65 \left(\frac{s}{D}\right)^4 + 31.014 \left(\frac{s}{D}\right)^3 - 4.3635 \left(\frac{s}{D}\right)^2 + 0.2469 \left(\frac{s}{D}\right) + 2.1656 \quad (59)$$

Equation (59) is the sixth-degree polynomial equation for $W/D = 2$ and has a value of $R^2 = 0.9988$.

$$K_t = -22.527 \left(\frac{s}{D}\right)^6 + 59.696 \left(\frac{s}{D}\right)^5 - 58.529 \left(\frac{s}{D}\right)^4 + 25.902 \left(\frac{s}{D}\right)^3 - 5.4764 \left(\frac{s}{D}\right)^2 + 0.537 \left(\frac{s}{D}\right) + 2.0842 \quad (60)$$

Equation (60) is the sixth-degree polynomial equation for $W/D = 2.5$ and has a value of $R^2 = 0.9997$.

$$K_t = 0.0486 \left(\frac{s}{D}\right)^6 + 4.7388 \left(\frac{s}{D}\right)^5 - 9.1404 \left(\frac{s}{D}\right)^4 + 5.9017 \left(\frac{s}{D}\right)^3 - 1.5939 \left(\frac{s}{D}\right)^2 + 0.1628 \left(\frac{s}{D}\right) + 2.0557 \quad (61)$$

Equation (61) is the sixth-degree polynomial equation for $W/D = 3$ and has a value of $R^2 = 0.9984$.

Conclusions

The results obtained show that the stress concentration factor decreases as the s/D ratio increases, at the same time the stress concentration factor decreases when the W/D ratio also decreases.

The linear equations obtained by the least square's method do not provide a good approximation because the R^2 values vary between 0.9354 and 0.8835, therefore they do not adjust adequately to the values obtained, it is not recommended to use these equations, only if it is desired to obtain a quick approximation of the stress values supported by the part.

On the other hand, the exponential equations obtained do not have a good approximation to the approximation to the values of the stress concentration factor obtained. stress concentration factor values obtained. The values of R^2 values vary between 0.9332 and 0.8810, so it is not also recommended to use these equations to predict the stress concentration factor. stress concentration factor.

The polynomial equations of second the second-degree polynomial equations obtained attach well to the calculated stress concentration factor values. of the calculated stress concentration factor. The R^2 values for these equations vary between 0.9761 and 0.9949, therefore, these equations provide reliable values of the stress concentration factor for the mechanical part under study.

On the other hand, the sixth-degree polynomial equations determined strongly fit the stress concentration factor values obtained. These equations have a value of R^2 that varies between 0.9964 and 0.9997, therefore the values of the stress concentration factor for the analyzed case study can be determined by these equations since the obtained values strongly fit the data calculated with the help of the finite element software.

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Indicate 3 keywords in Times New Roman and Bold No. 10

Citation: Surname (IN UPPERCASE), Name 1st Author, Surname (IN UPPERCASE), Name 1st Co-author, Surname (IN UPPERCASE), Name 2nd Co-author and Surname (IN UPPERCASE), Name 3rd Co-author. Paper Title. Journal Civil Engineering, Year 1-1: 1-11 [Times New Roman No.10].

* Correspondence to Author (example@example.org)

† Researcher contributing as first author.

Introduction

Text in Times New Roman No.12, single space.

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

What is your added value with respect to other techniques?

Clearly focus each of its features

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

Explanation of sections Article.

Development of headings and subheadings of the article with subsequent numbers

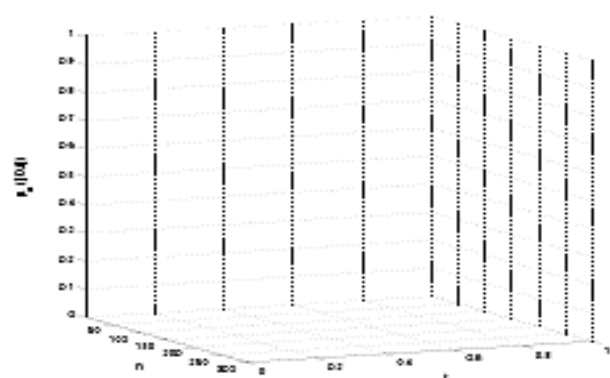
[Title No.12 in Times New Roman, single spaced and bold]

Products in development No.12 Times New Roman, single spaced.

Including graphs, figures and tables-Editable

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

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



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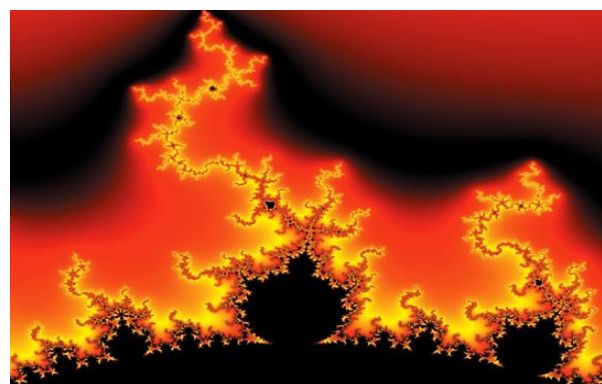


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Table 1 Title and *Source (in italics)*

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Each article shall present separately in **3 folders**:
a) Figures, b) Charts and c) Tables in .JPG format, indicating the number and sequential Bold Title.

For the use of equations, noted as follows:

$$Y_{ij} = \alpha + \sum_{h=1}^r \beta_h X_{hij} + u_j + e_{ij} \quad (1)$$

Must be editable and number aligned on the right side.

Methodology

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

Results

The results shall be by section of the article.

Annexes

Tables and adequate sources

Thanks

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

Conclusions

Explain clearly the results and possibilities of improvement.

References

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

Use Roman Alphabet, all references you have used must be in the Roman Alphabet, even if you have quoted an Article, book in any of the official languages of the United Nations (English, French, German, Chinese, Russian, Portuguese, Italian, Spanish, Arabic), you must write the reference in Roman script and not in any of the official languages.

Technical Specifications

Each article must submit your dates into a Word document (.docx):

Journal Name

Article title

Abstract

Keywords

Article sections, for example:

1. *Introduction*
2. *Description of the method*
3. *Analysis from the regression demand curve*
4. *Results*
5. *Thanks*
6. *Conclusions*
7. *References*

Author Name (s)

Email Correspondence to Author

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