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Also, the **ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering, Tome XVII [2024], Fascicule** 3 [July – September], includes scientific papers presented in the sections of:

- **ISB-INMA TEH' 2023 – International Symposium (Agricultural and Mechanical Engineering)**, organized by Politehnica University of Bucharest – Faculty of Biotechnical Systems Engineering (ISB), National Institute of Research-Development for Machines and Installations Designed to Agriculture and Food Industry (INMA Bucharest), Romanian Agricultural Mechanical Engineers Society (SIMAR), National Research & Development Institute for Food Bioresources (IBA Bucharest), National Institute for Research and Development in Environmental Protection (INCDPM), Research-Development Institute for Plant Protection (ICDPP), Research and Development Institute for Processing and Marketing of the Horticultural Products (HORTING), Hydraulics and Pneumatics Research Institute (INOE 2000 IHP) and "Food for Life Technological Platform", in Bucharest, ROMANIA, October, 2024. The current identification numbers of the selected papers are the **#1–4** and **#8–10**, according to the present contents list.

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INTEGRAL VALORIZATION OF OLEAGINOUS CROPS – A REVIEW

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Abstract: Worldwide, different oleaginous crops are cultivated, and according to statistics, an increase in the production of these crops is expected in the future. These oleaginous crops are mainly used for oil extraction and this oil can be used for food consumption and for biodiesel production. On the other hand, oilseed industry generates large amounts of by–products and waste. Oilseed cakes are the main residues generated after oil extraction. This article presents the oleaginous crops in biorefinary aspects, especially the biorefinary approach of the oilseed cakes, in order to minimize the agricultural waste and maximize value–added products.

Keywords: oleaginous crop, oilseed cake, biorefinery, agricultural waste

INTRODUCTION

The oleaginous crops are plants whose seeds or fruits have a high lipid content. They are the raw material for the extraction of vegetable oils and are grown mainly for this purpose. The resulted oil can be classified in edible oils (which are used directly for human consumption or as raw material in the production of margarine, mayonnaise, bakery products, pastry, canning etc.) and non–edible oils (which are used in the production of biodiesel, detergents, paints, pharmaceuticals or cosmetics etc.) *(Waseem, S. et al., 2017)*.

Worldwide, different oleaginous crops are cultivated, their production reaching 500 million tons between 2018 and 2020. According to statistics, an increase in the production of these crops is expected reaching 600 million tons by 2030 *(OECD–FAO, 2021)*. In 2022–2023 growing season, soybeans were the most popular type of oilseed. It was anticipated that worldwide would be produced just over 427.7 million tons of soybeans. In figure 1 it can be observed the worldwide most important oilseed crops and their production in 2022/2023 crop year *(www.statista.com)*.

Even if the soybeans represent the most produced oleaginous material, palm oil is the leader on the world's vegetable oil market. As it can be observed in figure 2, in 2021/2022, the worldwide production of palm oil was about 81.38 million tons, while soybean oil production totaled about 65.32 million tons. Figure 2 presents the worldwide evolution of vegetable oils consumption, from 2013/14 to 2022/2023, by oil type *(www.statista.com)*.

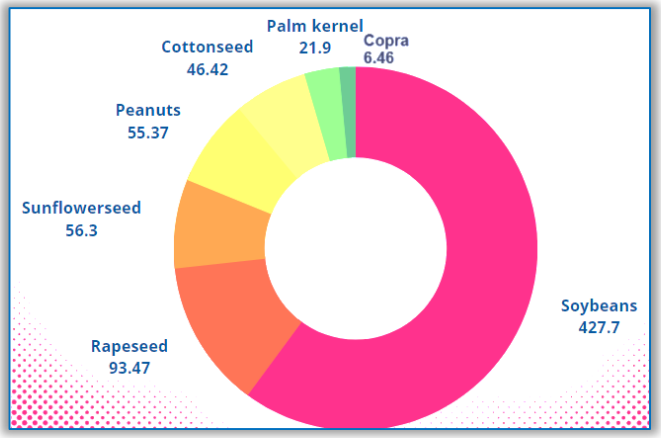

Figure 1 – Worldwide oilseed production in 2022/2023, by type (in million tons) *(plotted with data from www.statista.com)*

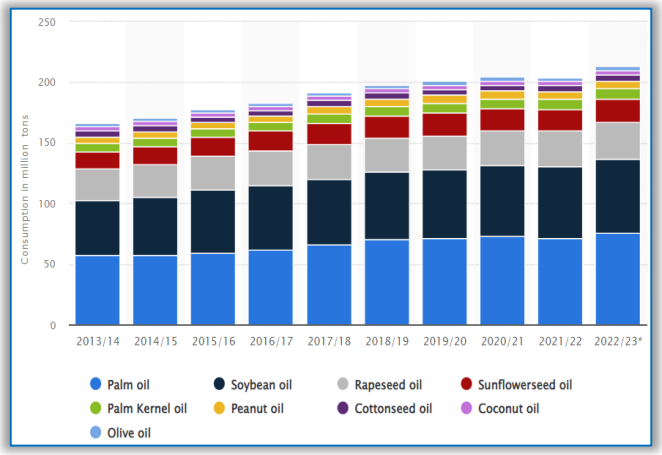

Figure 2 – Consumption of vegetable oils worldwide from 2013/14 to 2022/2023, by oil type *(www.statista.com)*

Large quantities of solid by–products (or agricultural wastes), known as oil cakes, are produced during the oil extraction process, and their production will undoubtedly increase over the next decade due to the high demand for vegetable oil. *(OECD–FAO, 2019; Singh, R. et al., 2022)*.

Through mechanical pressing, approximately 250–350 g of oil are recovered from 1 kg of oilseeds, and as a by–product, 650 g of de–oiled cake (seed cake) are produced. Therefore, around 65% of the oilseeds are left as residue (de–oiled cake), which is a large amount and justifies valorization in the context of the circular economy concept *(Rajpoot, L. et al., 2022)*.

"Sustainable management of food considers the food waste problem from the systemic perspective. Think of the many steps when waste can occur in the life cycle of food: agriculture, harvesting, food production, sales, food preparation, consumption, and finally disposal". The sustainable management of food decreases inefficiencies by controlling each of these phases *(www.greenly.earth)*. Figure 3 presents the estimation of food waste generated at the processing stage, by categories, in Europe *(Rakita, S. et al., 2023)*.

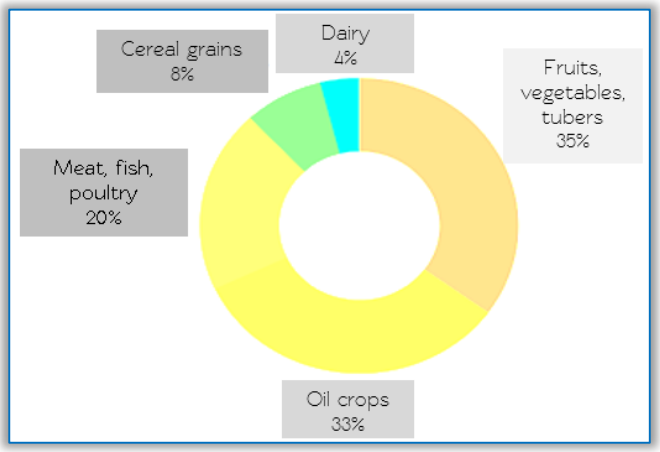

Figure 3 – Estimation of food waste generated at the processing stage, by categories, in Europe *(adapted from Rakita, S. et al., 2023)*

For oil extraction from oleaginous crops are used various methods, from which the most important are mechanical pressing and solvent extraction. The traditional technique for extracting oil is mechanical pressing, but this technique leave an important percent of oil in the oleaginous material. Another technique that is regularly used to recover the remaining oil from oleaginous crops is solvent extraction, which often involves the use of hexane as extraction solvent. The use of hexane in the extraction process in not in accordance with the demands of green chemistry, because hexane is a highly flammable substance, a volatile organic compound obtained from petroleum, and a CMR 2 (carcinogenic, mutagenic and reprotoxic) chemical *(Phan, L. et al., 2009)*.

Oilseed cakes can be divided into edible oilseed cakes (such as those obtained from sunflower, soybean, peanut, mustard) and non–edible oilseed cakes (which are made from sesame, castor, jatropha, and neem). Edible oilseed cakes can be used as animal feed or as ingredient in bakery products, because they presents a high content in protein and include a variety of antioxidants, vitamins, and fibers. Whereas, the non–edible oilseed cakes contain a high amount of toxic compounds and can be used in other application such as biopesticides, bioenergy, biopolymer, and bioelectricity *(Jangir, M. et al., 2020; Sunil, L. et al., 2015; Dias, A.L.B. et al., 2017; Naik K.S. et al., 2018)*. The integrated biorefinery concept is a process that convert biomass into energy and value–added products (https://www.sciencedirect.com).

This article presents the oleaginous crops in biorefinary aspects, especially the biorefinary approach of the oilseed cakes. The main advantages of biorefineries in an integrated perspective are minimizing agricultural waste and maximize value–added products, in the context of circular economy concept.

APPLICATIONS OF OILSEED CAKES AS EDIBLE PRODUCTS

Oilseed cakes are agriculture waste obtained from the oil processing industry. In other words, oilseed cakes represents the residues remaining after the partially oil removal from the oilseeds. Therefore, the oilseed cakes that are produced present a higher protein content. In accordance to a waste management system, it is necessary to use oilseed cakes as a functional ingredients that may be included into different foods *(Kotecka–Majchrzak, K. et al., 2020)*. Due to variations in oilseed quality, oil extraction techniques, and storage conditions, the oilseed cakes have different compositions and nutritional contents *(Kapoor, M. et al., 2016)*.

Nearly all food categories, such as dairy, bakery, beverage, confectionery, and baby food industries, have functional foods on the market. Therefore, underused oilseed cakes receive growing attention from researchers as functional ingredients in food items *(Siró, I., et al., 2008)*.

In the beverage industry, the researchers analyzed the flaxseed cake–based fermented beverages in comparison with kefir as substrate. Three different experiments that contained flaxseed cake at variable concentrations of 5%, 10%, and 15% w/w were successfully used to inoculate kefir grains *(Łopusiewicz, Ł. et al., 2019)*.

Edible oilseed cakes that are rich in protein and fiber can be added to various bakery products, such as cakes, cookies, and bread *(Bochkarev,*

M.S. et al., 2016). Another study utilized poppy, sesame, chia, and flaxseeds cakes to replace the wheat flour in the recipe of cookies.

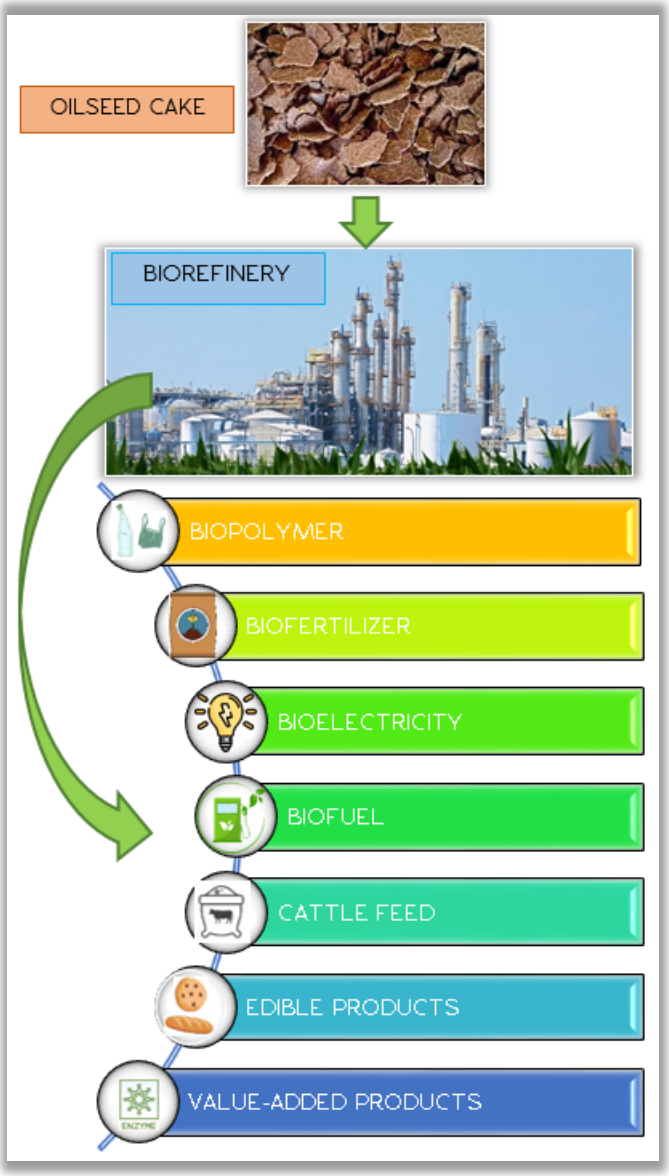

Figure 4 – Biorefinary approach of the oilseed cakes
(*adapted from Sarkar N. et al., 2021*)

The nutritional profile of the cookies was increased with this innovation *(Martinez, E. et al., 2021)*. Also, hemp seed meals were used in different amount, along with the rice flour, to produce energy bars (*Norajit, K. et al., 2011*).

Due to the therapeutic potentials of oilseeds and by–products (antidiabetic, cardio protective, antimicrobial, anticarcinogenic, neuroprotective), researchers realized compressed tablets from sunflower, coconut, pumpkin, and flax cakes, that were utilized as supplements *(Sobczak, P. et al., 2020)*.

The proteins and fibers from oilseed cakes were used to replace the meat in different food products. For example, researchers tried to partially replace the porcine and beef meat mixture from hamburgers with soy and chia meals. The results showed that this innovation conduced to a higher quality product *(Souza, A.H.P. et al., 2015)*.

An important percent of crude protein is found in oilseed cakes. For example, the oilseed cakes obtained from copra, sesame, and palm kernel contain 14–20% crude protein, while the groundnut cake has 40–5–% crude protein. Thus, these cakes are used to make value–added products in the field of fermentation and enzyme technology *(Sunil, L. et al., 2015)*. Used as a substrate or as a supplement for production medium in the solid–state fermentation, the oilseed cakes from sesame, soybean, coconut, olive, and palm, improved the enzymes production, such as protease, lipase (*Gupta, A. et al., 2018 –1; Gupta, A. et al., 2018 –2; Treichel, H. et al., 2010)*. For the proteases and cellulases production, as value–added products, mahua and jatropha oilseed cakes were utilized (*Nagegowda, D.A. et al., 2020*). The utilization of sal oilseed cake increased the yield of protease obtained by *Aeromonas* sp. S1 (*Saini, G.A. et al., 2020)*. Coconut oilseed cake was utilized to produce neutral metalloprotease and amylase, using *A. oryzae* (*Sumantha, A. et al., 2005; Joo, C.S. et al., 2002*), while palm and palm kernel cakes were used to produce different enzymes, using *A. niger* (*Ramachandran, A. et al., 2004*).

Other study showed that in solid–state fermentation, an increase in the yield of mushrooms was obtained when cotton cake was used; also, a higher content of protein and fat was observed in the mushrooms (*Jatuwong, K. et al., 2020*).

Another utilization of the oilseed cakes refers to the antibiotics and antimicrobials production. Sesame cake was involved in the antibiotic production; soybean, sesame and sunflower cakes were utilized for clavulanic acid and cephamycin C production; for obtaining Bacitracin was used sunflower cake, while *Bacillus licheniformis* and *Bacillus thuringiensis* were produced with sesame cake (*Usman, I. et al., 2023*).

OTHER APPLICATIONS OF OILSEED CAKES

The use of organic fertilizer, a good substitute for artificial fertilizer, is demonstrated in numerous studies and researches. The most important advantage of organic fertilizer over chemical fertilizer is that it transforms nitrogen into a less soluble form *(Aziz, S. et al., 2018)*. Due to the phosphorous, nitrogen, and potassium content, many of the non–edible oilseed cakes (cottonseed, mahua, karanja, neem, and

castor) are utilized as organic fertilizers (*Ramachandran, S. et al., 2007*). The utilization of cottonseed cake as organic fertilizer was demonstrated in a study where the cottonseed cake composition was investigated by Atomic Absorption Spectroscopy *(Aziz, S. et al., 2018)*.

Recent research focused in producing biogas with the aim of oilseed cakes. The studies also investigated the factors involved in the biogas production, such as pre–treatment methods, type of inoculums and operation parameters (*Sriti, J. et al., 2013*). In order to produce biogas from oilseed cakes the method of anaerobic digestion is used *(Ben–Youssef, S. et al., 2017)*. The productivity of bioconversion depends on the biomass's lignin content. It has been possible to enhance the availability of biodegradable material in lignocellulosic biomass via several functional and physicochemical features. One of the by–products that is suitable for biogas production is represented by jatropha seed cake *(Deepanraj, B. et al., 2021)*.

Another application of the oilseed cakes is as biomass–producing electricity. This application is very important for areas where electric facilities does not exist. In a study, briquettes obtained from jatropha oilseed cake were successfully used in an electricity–generating machine *(Gutiérrez, C. et al., 2010)*.

Due to the high concentration of polysaccharides and proteins, oilseed cakes are a unique polymeric substance that is used to create a variety of biopolymer film–based packaging materials *(Ancuța, P. et al., 2020)*. The biopolymer films obtained from oilseed cakes present a favorable gas barrier properties under low moisture circumstances, and various characteristics of the biopolymer films can be improved through several optimization procedures *(Popović, S. et al., 2020)*. The oilseed cakes represent a natural composite, which can be successfully used at the polymer fiberboards production. This process involves the thermo–pressing of the oilseed cake. The oilseed cake protein improves the fiber's consistency and entanglement *(Saini, G.A. et al., 2013)*. The biopolymer obtained is renewable, biodegradable and environmental friendly, thus the production of agro–materials by oilseed cakes thermo–pressing represents an innovative solution for valorization *(Sarkar N. et al., 2021)*.

The proteins, vitamins, electrolytes content of the oilseed cakes improve the performance of the animals when is used as a supplement in animals diet. Also, the animal metabolism is improved due to the linoleic acid content of the oilseed cakes *(Sarkar N. et al., 2021)*. In addition, the oilseed cakes can be utilized as an aquaculture feed for fish. An improvement in the fish fillet texture and a growth rate of the fish was observed when the fish diet contained hempseed cake (*Lunger, C.S. et al., 2007; Callaway, J.C., 2004*).

CONCLUSIONS

After cereals, oilseeds are considered to be the second most significant factor affecting agricultural economies. Large quantities of solid by–products (or agricultural wastes), known as oilseed cakes, are produced during the oil extraction process, and their production will undoubtedly increase over the next decade due to the high demand for vegetable oil.

It is known that around 65% of the oilseeds are left as residue (de–oiled cake), which represents a large amount of agricultural waste. Thus, in accordance to a waste management system, it is necessary to use these oilseed meals in a sustainable way, contributing to the development of low–cost, and novel products while reducing food waste disposal.

The available studies from the literature, presented the importance of these oilseeds' by–products in the context of the circular economy concept. Taking into account that oilseed cakes have an important content of proteins, fibers, and bioactive compounds, they are recommended as functional ingredients in food items (such as meat, bakery, and beverage industry products), as substrate for enzymes and mushroom production, or in the antibiotics and antimicrobials production.

Beyond the nutritional value, the oilseed cakes valorisation will help in accomplishing the zero–waste challenge. In this purpose, other applications of the oilseed cakes are developed, such as: the oilseed cake use as organic fertilizer, the biogas production by anaerobic digestion of substrate enhanced with oilseed cakes, the oilseed cake use as biomass–producing electricity, the use of oilseed cake at the biopolymer production or the oilseed cake use as a supplement in the cattle feed.

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INFLUENCE OF SOME ADDITIVES – BINDER AND NUTRIENT SOURCES, ON SOME CHARACTERISTICS OF BIOSOLID FERTILIZER GRANULES

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Abstract: Obtaining granular biosolid fertilizers by extrusion requires the addition in the manufacturing formula, in addition to some minerals to improve the nutrient composition, of certain substances that also have a binder role to ensure physicochemical characteristics that meet the requirements of the organo–mineral fertilizer category. Granules obtained from two recipes using starch, molasses and urea both as a nutrient source and as a binder in the extrusion process were studied. The paper presents research on the influence of binder additions on physico–chemical characteristics of biosolid–based granular fertilizers, such as particle size fraction, grain moisture, pH and compressive strength.
Keywords: biosolid, granular, molasses, physico–chemical characteristics

INTRODUCTION

The use of sludge in agriculture can contribute to reducing environmental pollution due to the disposal of waste sludge from wastewater treatment plants, thus avoiding incineration or other polluting and costly processes (*Adugna G., 2016; Bowszys T. et al., 2015*).

Biosolids for agriculture are obtained from raw sewage sludge by digestion and stabilisation processes. These processes ensure the reduction of toxic chemicals and pathogen concentrations in sludge so that its use in agriculture does not harm soil, plants, groundwater and not least the health of consumers of agricultural plant and animal products (*Kominko H. et al., 2018; Kumar V. et al., 2017; Pöykiö R. et al., 2019*).

The nutrient content of biosolids varies depending on the quality of the sludge from which they come, as well as the technologies used to stabilize the latter (*Azim K. 2017; Bożym M. and Siemiątkowski G., 2018; Popa M. et al, 2019*). A fertilizer made by mineral and organic (biosolids) fertilizers combined give us a variety of advantages (*Parent L.E.et al. 2003*).

In order for biosolids–based organo–mineral fertilizers to be balanced in content it is necessary to add in the manufacturing recipes chemical compounds which generally contain both the three nutrients N, P and K, indispensable for plants, as well as micronutrients (*Kominko H. et al., 2017*).

The best production technology used to improve the transport, storage and application properties of organo–mineral fertilizers is granulation (*Deeks L.K. et al., 2013*). One of the most modern applicable methods for granulating organo–mineral fertilizers is reactive extrusion which, by being a thermo–mechanical process, ensures in addition to good compaction and the development of chemical reactions between components, which leads to a homogeneous physical and chemical structure of granules.

The characteristics of granular organo–mineral fertilizers based on biosolids must correspond to the existing requirements imposed on organo–mineral fertilizers. The knowledge of the physical – chemical characteristics of the fertilizers contributes to the assurance of their proper management.

MATERIALS AND METHODS

The granular fertilizer material based on biosolids was manufacture by reactive extrusion and then granulation, according to the two variants of manufacturing recipie (Table 1) in which the organic part is provided by biosolids, protein hydrolyzate and molasses (*Cioica N. et al, 2020*). In addition to organic and mineral components, for both Sample I and Sample II starch has been added to the reciepis to provide the matrix required for reactive extrusion processing. In addition, Sample I also contains molasses both as binder and as source of organic nitrogen and potassium.

The experiments aimed to determine the influence of the addition of molasses in the granular fertilizer recipie on its properties. The properties studied were particle size fractions, particle moisture, compressive strength and pH.

In order to determine the particle size fractions, samples of about 50 g of each Sample were

sieved through diferent sieves with an eye size of 4; 2; 1; 0.5 and 0.25 mm.

Table 1. Composition of manufacturing recipies

No.	Substance in formula	Percentages, %	
		Sample I	Sample II
1	Dry biosolid, 20% humiditaty	30.00	30.00
2	Monoammoniumphosphate (MAP)	24.50	25.00
3	Potassium nitrate	22.20	23.00
4	Urea	5.30	6.20
5	Starch	7.98	7.50
6	Protein hydrolyzate, 11 % solution	4.00	4.00
7	Molasses from sugar beet	*2.23*	*0.00*
8	Manganese sulfate	3.30	3.56
9	Zinc sulfate	0.08	0.09
10	Copper sulfate	0.05	0.06
11	Iron sulfate	0.11	0.11
12	Manganese sulfate	0.22	0.24
13	Cobalt sulfate	0.03	0.03

Figure 1 – Determination of moisture content with thermobalance AXIS –100

To determine the particle moisture samples of about 5 g of granules, were dried with a thermobalance type AXIS–100 at 80°C (Figure 1). At every 20 seconds the masses were recorded until at least 3 consecutive equal values were obtained. The moisture content was determined by the difference between the initial mass of the samples and the final mass (after drying).

For the most of cultivated plants the consumption of nutrients depends directly on the pH. For example calcium and magnesium are easily assimilated by plants at pH 7 – 8.5, nitrogen at pH 6.0 – 6.8, phosphorus at 6.5 – 7.5, potassium at higher pH of 6, and the trace elements are assimilated more easily in the acidic environment.

Therefore, any organo–mineral fertilizer must ensure that the pH is kept within optimal limits for plants. In order to determine the pH of the biosolid based fertilizer (Figure 2), samples of 10 g granules were dissolved in 100 ml of distilled water, every 15 min the pH was measured with pH indicator paper from Merck.

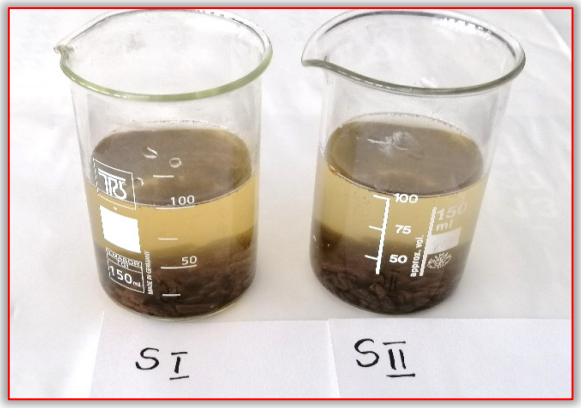

Figure 2 – Granular fertilizer based on biosolid dissolved in distilled water

The compression tests (Figure 3) were performed for biosolid based granules with a manual press equipped with a 5 kN force transducer, the data being taken over and processed by means of a Spider 8 data acquisition plate. One granule of fertilizer from each Sample was used for the measurements and the measurements were repeated by 5 times to determine the average value of the compressive strength for each variant.

Figure 3 – Test equipment for determining the compressive strength of granular fertilizer material based on biosolids

RESULTS

In table 2 are presented the results obtained from the granulometric analysis of the granular organo–mineral fertilizer based on biosolids.

From the analysis of the data obtained we observe that the granules in both variants falls within the technical requirements established by EC Regulation no. 2003/2003 regarding the granulometric structure of fertilizers, namely: min. 90% between 1 and 4 mm and max. 10% less than 1 mm or more than 4 mm. Also, the addition of molasses (Sample I) leads to a slight increase in fraction in the percentage of granules between 1 and 2 mm.

Table 2. Granulometric composition of the samples of fertilizer based on biosolid

Granulometric fraction	Granule mass,g / percentage parts,%			
	Sample I (with molasses)		Sample II	
between 2 and 4 mm	43,10	85,6%	45,81	91%
between 1and 2 mm	6,46	12,8%	4,22	8,4%
between 0,5 and 1 mm	0,52	1%	0,18	0,4%
between 0,25 and 0,5 mm	0,21	0,4%	0	0%
< 0,25	0,09	0,2%	0,09	0,2%
Total	50,38	100%	50,30	100%

Table 3. Values of moisture content, water absorption capacity and ph in solution

Characteristics	U.M.	Fertilizer material based on biosolids	
		Sample I (with molasses)	Sample II
Moisture content	%	1,33%	1,70%
pH in solution		between 5 –6	between 5 – 6
Water absorption capacity	%	47,9	50,7

Analysing the data obtained and presented in table 3, we note that the moisture content falls within normal limits, the higher value being registered for Sample II–with no molasses. Also the water absorbtion capacity is slighty higher for the Saple II without molasses.

The values of pH, measured for a solution of 100 ml of distilled water and 10 g of biosolids fertilizer, are between 5– 6.

Figure 4 – pH in solution for Sample I–with molasses and Sample II without molasses

Good properties in terms of transport, storage and application of granular form of biosolids based fertilizers can only be ensured by knowing the compressive strength of the granules.

From the graphs shown in Figure 4 and Figure 5 it can be seen that for both Samples we observe an almost linear behaviour of the granule deformation in relation to the applied compressive force. For both Samples with or without molasses in composition, the maximal values of compressive strength is between 40 and 50 N.

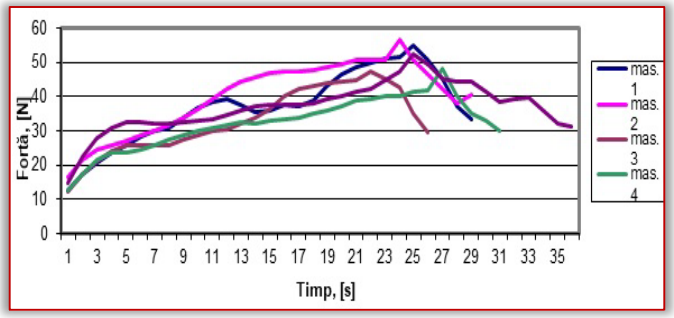

Figure 5 – Diagrams of compressive strength for Sample I– with molasses

Above these values of compressive strength, the granules do not deform anymore during mechanical stress.

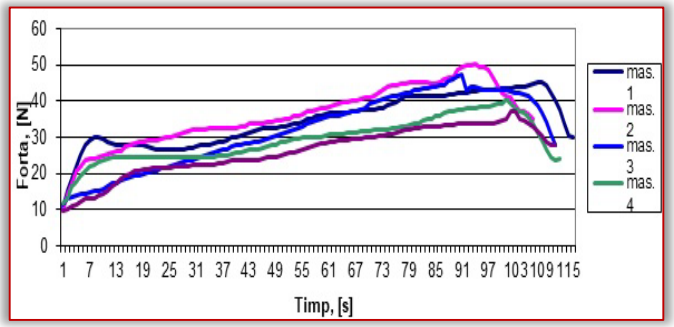

Figure 6 – Diagrams of compressive strength for Sample II – without molasses

CONCLUSIONS

Granulometric structure of the granular fertilizer falls within the technical requirements established by EC Regulation no. 2003/2003, namely: min. 90% between 1 and 4 mm and max. 10% less than 1 mm or more than 4 mm. For both samples we obtained 98–99% for fraction between 1 and 4 mm and 0,6–1,6% for the fraction less than 1 mm, so molasses content do not influence the granulometric structure.

From the analysis of the data resulting from the measurements made, it is observed that the material obtained in both variants has values of compressive strength between 40 and 50 N;

In both Samples, the moisture content tested falls within normal limits, the higher value being registered in Sample II which contains no molasses, in which case also, the water absorption capacity is higher;

The pH measured in solution of both Samples falls between 5–6, so the molasses content seems to not influence the pH of granular fertilizer;

The researches highlighted the fact that the applied manufacturing recipes allow to obtain granular biosolid based fertilizer that falls within

the requirements imposed for organo–mineral fertilizers;

The addition of molasses as binder and source of organic nitrogen and potassium, was a good choice to obtain granular fertilizer based on biosolids trough reactive extrusion.

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DIGITALIZATION IN THE AGRICULTURAL SECTOR

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Abstract: The agricultural sector has never ceased to innovate, and each generation brings new technological and organizational improvements, as well as new skills. However, the accelerated pace of technological innovation is faster than ever, and it is crucial for European farmers to fully benefit from this "digital revolution". The challenge lies in truly understanding the added value of these technologies, in deciding which ones are worth investing in, when to make these investments, and to what extent. In the European Union (EU), the "digital transformation" already plays an essential role in rural environments and in the agricultural sector. For example, the adoption of modern agricultural technologies, including those involving robots, the Internet of Things (IoT), and big data analysis, has significant potential to lead to more productive, sustainable, and environmentally friendly food production. Smart farming systems can assist farmers in making better decisions and developing more efficient operational and management practices.
Keywords: digitalization, agricultural sector, ICT, clound computing, environmental policies

INTRODUCTION

Information and Communication Technologies (ICT) are reshaping the world we live in. "Cloud computing," "Internet of Things," location–based monitoring, "social media," "blockchain," and "big data" represent unprecedented technologies and innovations that have led to innovative business models across multiple industries. These technologies are rapidly integrating into agriculture and food supply chains, spanning from the agricultural machinery industry and food processing to logistics, retail, and even consumers when it comes to food and health applications. These innovations encompass new business models and will likely bring about new changes in the organization of the entire agri–food chain, (*Anshari, M. et al, 2018*).

This has been acknowledged through the Cork 2.0 Declaration, "A Better Life in Rural Areas," which develops policy guidelines for innovative, integrated, and inclusive rural and agricultural policies. The Cork 2.0 Declaration has laid the foundation for facilitating digital transformation in agriculture and rural areas. It underscores the need for investments to harness the potential offered by connectivity and digitization in rural regions. Additionally, it emphasizes the importance of fostering research and innovation is essential to ensure that businesses in rural areas, including farmers, have access to appropriate technologies, state–of–the–art connectivity, as well as new management tools to bring about economic, social, and environmental benefits. Furthermore, as part of the strategy for developing the Digital Single Market, on April 19, 2016, the European Commission (EC) launched the Communication on "Digitising European Industry" (COM(2016) 180), the overall aim of which is to ensure that "every industry in Europe, big or small, wherever and in whichever sector, can fully benefit from digital innovations to enhance its products, improve its processes, and adapt its business models to the digital transformation, (*Stoian M, Aniței M. 2019*)." This requires the full integration of digital innovations across all sectors of the economy, including the agricultural and food sectors.

In the realm of product innovation, existing products (such as agricultural machinery) become much more data–intensive in terms of collection and utilization through the aid of ICT applications.

From a certain perspective, we can say that the hardware or offered product transforms into a service. This model is favored by tractor and agricultural machinery manufacturers, as well as producers of milking robots or developers of greenhouses and animal shelters, (*Stoian M, Aniței M. 2019*). Examples include agricultural machinery companies like the American company John Deere, which gathers data from the agricultural machinery sold to farmers. This encompasses the machines' locations, engine hours, operational data (such as fuel usage), and machine diagnostics. All the data is collected in the web portal MyJohnDeere.com. Another example is the Dutch company Lely Industries, which produces milking robots and

collects data regarding the performance of each cow.

In such a model, the data collected through ICT applications is exchanged between (for example) farmers and food producers in order to enhance the service component of the transaction. Examples demonstrate that software can be provided by agricultural product processors to support farm management while simultaneously improving the production or marketing processes of the food company. The UniTip software of the Dutch sugar cooperative Cosun is an example: farmers can record their field data in the cooperative's software (*Stoian M, Aniței M. 2019*). They subsequently receive management advice and indicators for measuring the economic performance of the farm.

At the same time, cooperatives utilize the data obtained through these applications to organize their logistics, production planning, and marketing (since it can provide customers with sustainability data). In this example, the pressure from the food and beverage industry for sustainable on–farm production methods led certain cooperatives to decide to make ICT software mandatory for their members by 2019, (*Birner, R. et al, 2021*).

Short supply chains that directly link consumers to farmers have many attractive characteristics for both parties. This can mean lower prices, better traceability, a better understanding of how products are obtained, increased sustainability, and contribute to the development of local communities, to name just a few of their advantages. Agricultural shops and farmers' markets are classic ways of organizing short supply chains. An extremely successful and interesting example comes from Finland. REKO is a system of direct sales from producers to consumers. It is incorporated into Facebook, where volunteer administrators manage closed Facebook groups with producers and consumers as members. Such groups are very easy to establish (from the perspective of the necessary information and communication technology): a group is formed, farmers post their offers weekly, and consumers use the commenting option on Facebook to place orders, (*Donaldson, A. 2022*). Orders are delivered to a central point and at a specific time interval for pickup and payment (for example, Saturday mornings between 10:00 and 11:00 at the local school's parking lot). Existing retailers are often happy to allow the transfer of products to their own parking areas, hoping that this will lead to consumer visits to their store for other products, (*Deng, H.Y. et. 2022*). The characteristics of this solution are that it's completely free for everyone (both producers and consumers), requires very little administration, and there are no intermediaries. By utilizing an established social media tool, there are no costs for developing and maintaining an ICT application. Three years ago, REKO launched two projects in the western part of Finland. It went well, and now there are more than 130 projects (REKO circles), with a total of over 180,000 involved members. The estimated turnover is 30 million euros annually. The initiator, Thomas Snellman, has received several awards for his initiative. This example shows that not always the technology itself, but the aspect of social innovation, creates new opportunities with a data–driven business model.

In a value chain integration business model, activities within an existing chain are organized through ICT in an alternative way, as the availability of data makes decision–making at a different point in the chain more efficient. An example is prescriptive agriculture, where a portion of the decision–making process is shifted from the farm to software at a different level of the value chain. A European example in the realm of services is the Dutch–Flemish breeding cooperative CRV, which assists dairy farmers in their insemination decisions for cows. While traditionally the farmer estimated whether a cow was in heat and ready for insemination, sensors have taken over this detection. CRV has developed an application that not only signals this status but also suggests semen from three possible bulls, and the delivery is done automatically, (*Fountas, S. et al, 2020*).

MATERIAL AND METHOD

Business models that create value from data by establishing new value networks essentially represent platforms that connect different customer groups and support their interaction. There is often an element of co–creation: the data from one group triggers activities of the other group and vice versa. Sometimes these platforms have strong network effects: it's attractive for users to join a platform where other customers have already subscribed, as seen with platforms like LinkedIn or Facebook. In agriculture, several platforms have been created that form ecosystems of applications. European examples include 365Farmnet and Akkerweb. Another example is the EU project FI Space (Future Internet Collaboration Space), now

available for commercial exploitation, offering a collaboration platform between enterprises that could connect platforms like MyDeere.com, 365Farmnet, Akkerweb, Agriplace, and others through an open–source model like Linux. Several EU FI–PPP accelerator projects such as SmartAgrifood, FINISH, and Fractals utilize this platform (*Klerkx, L.; et al, 2019, Stoian M, Aniței M. 2019*).

We are certainly aware of the issues facing Romanian agriculture, such as the fragmentation of agricultural lands, property disputes, the subpar state of agricultural infrastructure and irrigation systems, and the precarious state of mechanization. However, the purpose of this essay is not to detail these problems, but to propose a few steps to encourage farmers to adopt ICT solutions that can enhance the economic performance of farms.

The emergence and adoption of biosensors, nanotechnology, low–cost electronics, the Internet of Things, and remote sensing devices, among others, increase the importance of business models based on these technologies. However, it is clear that in the case of Romania, we are still in the early stages. We have the opportunity to connect existing initiatives by bringing interested parties closer together. This provides people with the chance to discuss, test, and enrich their ideas as they meet with other members of the community. Below are a few important principles to consider, (*Hackfort, S. 2021*).

Certainly, I understand that you do not wish to detail the specific problems of Romanian agriculture but to propose steps to encourage farmers to adopt ICT solutions to enhance farm economic performance. Let's delve further into this topic:

To encourage farmers to adopt ICT solutions that can improve farm economic performance despite specific challenges, you can propose the following approaches:

- Raising Awareness of Advantages: Education and awareness are essential. Encourage farmers to understand the benefits they can gain by adopting ICT technologies, such as increased yield, resource efficiency, and making more informed decisions.
- Governmental Support: Encourage the government to provide financial support or incentives for farmers adopting ICT technologies. This might include grants for equipment purchases or training programs.
- Partnerships with Universities and Research: Collaboration with higher education institutions and research centers can help develop and tailor ICT solutions to the specific needs of Romanian agriculture.
- Information and Communication Platforms: Establishing information and communication platforms within agricultural communities can aid in sharing knowledge and experiences related to using ICT technologies.
- Demonstrations and Awareness Events: Organize practical demonstrations and awareness events to show farmers how they can use ICT technologies in their daily activities.
- Sharing Successful Case Studies: Share success stories where farmers have successfully implemented ICT solutions and achieved positive results in terms of productivity and economic performance.
- Support Groups and Networks: Encourage the formation of support groups and networks of farmers who share common interests in adopting ICT technologies. These groups can provide support, advice, and resources.
- Access to Financing: Facilitate farmers' access to financing for acquiring ICT technologies through programs offering low–interest loans or partnerships with financial institutions.
- Testing and Evaluation of Solutions: Organize testing and evaluation programs for ICT solutions in collaboration with farmers. This can help identify the most suitable solutions for each farm's specific needs.
- Promotion of Collaboration: Incentivize farmers to collaborate in the use of ICT technologies. Sometimes, costs can be reduced through joint equipment purchases or knowledge sharing.

In conclusion, adopting ICT technologies in agriculture requires an integrated approach that combines education, government support, and collaboration among different stakeholders to ensure an efficient and beneficial transition for both farmers and the industry, (*MacPherson, J. et al. 2022, Stoian M, Aniței M. 2019*).

RESULTS

New business models based on ICT applications and sensors are being implemented in agriculture and the food supply chain. They greatly increase the amount of data collected and available in agricultural sectors and throughout the supply chain (from farm to fork). The emergence and adoption of biosensors, nanotechnology, low–cost electronics, the

Internet of Things, and remote sensing devices, among others, will further enhance the significance of the data domain.

The government can provide support for agricultural innovators in many ways, from (financial) support for beginners to research projects whose results can be utilized in commercial applications, to establishing innovation hubs in agriculture that offer farmers the opportunity to discuss, test, and enrich their ideas while engaging with other members of the agricultural community, (*Namani, S. et al., 2020*).

A primary opportunity would be to include agriculture in the national strategy for the digital agenda as one of its most important pillars. The JASPERS study "Analysis and Evidence Base of the R&D&I Market in Romania" identified agriculture as one of the four economic sectors with the highest development potential in our country.

Access to appropriate IT infrastructure is a fundamental aspect. An extensive broadband network that reaches all rural areas, including remote ones, access to powerful servers, the development of technology competence centers, and other physical infrastructures are basic requirements. Without investing in infrastructure, the opportunities for capitalizing on information technologies are significantly limited, which is why these types of investments need to be treated as a priority. Possible paths to follow could include supporting the development of new ICT tools for agriculture, promoting innovation and cooperation, as well as facilitating investments, (*Runck, B.C. et al, 2022*).

For financing specific innovative actions, the EIP–AGRI is implemented through initiatives primarily supported by two EU policies: the Rural Development Policy and Horizon 2020. The funding, implementation, and prioritization of actions occur through the implementation mechanisms embedded within these respective policies. Operational Groups (OGs) are key entities that operate within the EIP–AGRI framework. These groups bring together farmers, agricultural advisors, researchers, businesses, and other relevant stakeholders (such as civil society, including NGOs and governmental bodies).

The European Commission provides a high degree of flexibility regarding the size, composition, and specific commitments of OGs. An Operational Group must develop a plan that describes the proposed project and the expected outcomes. Additionally, OGs are required to disseminate the results of their projects, particularly through the EIP–AGRI network.

The exact content of a project plan depends on the involved actors and the issue, challenge, or opportunity that needs to be addressed. An innovation broker can help identify innovative ideas and assist partners in connecting and forming an OG around concrete projects.

Within Horizon 2020, two new instruments have been developed to support EIP–AGRI projects: multi–actor projects and thematic networks. The key feature of multi–actor projects is to address the needs, issues, and opportunities of end–users and generate the necessary interaction between researchers and end–users, such as farmers/producers, agricultural advisors, and businesses, by assigning distinct roles to different actors within the project.

The renewed interest in agricultural innovation policies (both at the EU, national, and regional levels) is undoubtedly commendable, as it focuses on a crucial determinant, if not the most important one – the long–term competitiveness of our agricultural enterprises. However, this interest doesn't always follow an adequate approach concerning the fact that much of the evidence and beliefs related to innovative processes in agriculture, considering the past, are susceptible and may risk losing relevance in today's times or at least are relevant for defining an appropriate strategy, (*Ruan, J.H. et al, 2020*).

The last century has been characterized by a remarkable growth in agricultural resource productivity. In the latter half of the past century, global agriculture experienced significant performance growth. Over the past 50 years, yield per hectare increased by nearly 150%, agricultural labor productivity by nearly 75%, and total factor productivity by about 55%, (*Wolf, S.A et al., 1996*).

In this process, those forms of knowledge, informal and gradually spread tacit innovative processes, constituted the real engine behind the "miracle" of productivity growth in the last century. Besides the primary challenge of the past century, the ability to produce enough food for a growing population in both number and consumption levels (food security), there remains another key issue: this challenge can only be won today under strict conditions, (*Shepherd, M et al., 2020*). The main condition is that of compatibility with the environment, or more precisely, sustainability. The second condition is that of multifunctionality.

The agriculture of the future will necessarily have the capacity to produce, in addition to food, other public non–food goods and services or collective interest services. Of course, among these are environmental services that lead us back to sustainability, but especially in affluent and post–industrial societies, agriculture is also needed to produce landscapes and aesthetic values, cultural and recreational services, physical and mental health, increased well–being, and more. We are the guarantor, as the first link in the food supply chain, of food safety and food quality, which means we ensure the safety, nutritional, ecological, and ethical quality of food, as well as their origin and provenance. However, sustainability and multifunctionality require a generation of knowledge and innovations of a different nature than the conventional challenge of food security, (*Subaeva, A.K. et. al. 2020*).

The process of innovation must, therefore, be redesigned to address these challenges and capitalize on the opportunities presented by ongoing technological changes. This reorganization can be managed through the progressive emergence of a genuine technological paradigm and the new technological trajectories that stem from it. The emerging General Purpose Technologies (GPTs), which are already dominant, or at least highly promising for future development (ICT, microelectronics and nanotechnology, modern biotechnology, neuroscience, robotics, advanced materials, photonics) have a potentially as broad application in agriculture as those of the last century, but with a substantially different nature (*Walter, A., 2016*).

CONCLUSIONS

An important goal in modern agricultural practices is that production should become less intensive and more integrated into systems aimed at reducing the use of fertilizers, pesticides, and especially minimizing the consumption of natural resources (water, soil, energy). The primary objectives of these systems should be to sustain both crop yields in quantitative and qualitative terms, preferably maintain or enhance agricultural income, and minimize the negative impact on the environment as much as possible.

Agriculture, a highly significant sector in our lives, couldn't remain disconnected from IT. If you asked a farmer 10–15 years ago whether they used a computer, now the absence of a computer and the lack of software applications for their agricultural activities is inconceivable. Currently, we talk about IT in agriculture in three main directions: as a tool for agricultural productivity, as an information tool for decision–making in agricultural and related activities, and as a tool for managing and ensuring subsidies and funds for agricultural modernization.

Currently, in agriculture as in any other field, the efforts and trends are focused on enhancing agricultural efficiency, and this is made possible thanks to new technologies. These new technologies encompass the construction of machinery used in various agricultural activities, the provision of high–performance inputs adapted to new climate conditions, and notably, the delivery of IT solutions that facilitate operations in this sector. The European Union also places special importance on this direction, providing support and programs. All of these efforts aim to help farmers produce more while ensuring the quality of food.

IT practically finds its way into each of the above–mentioned directions, and the term "precision agriculture" encompasses all of these aspects. A simplified description of precision agriculture is to "apply the right treatment in the right place at the right time". It is a concept based on observing, measuring, and responding to variability within agricultural crop management or aspects related to animal husbandry. Additionally, another frequently used term is IoT (Internet of Things), which essentially involves using the internet to connect all devices, in this case, that can add value in the agricultural domain.

To achieve high performance in agriculture, you need to combine diverse information gathered from various sources: field data, soil maps, weather information, humidity levels, pests, vegetation indices, planting recipes, and more. For each of these aspects, there are software solutions available, ranging from simple to complex, to assist farmers. To address all of these challenges, farmers have started seeking solutions that can integrate all this information. Initially, there were separate applications addressing specific aspects, but now integrated solutions are in high demand. Moreover, due to the rapid evolution of technology, such applications need to be optimized for mobile devices, such as phones and tablets.

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ABOUT THE DESIGN AND BEHAVIOUR IN TIME OF TANKS USED FOR ANAEROBIC FERMENTATION OF SLUDGE BY–PRODUCTS RESULTED FROM WASTEWATER TREATMENT PLANTS

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Abstract: The following article aims to point out the complex connection between the concept, design and construction requirements and behaviour in time of one of the key objects used in the biological treatment stage of wastewater, the tanks used for anaerobic sludge fermentation. The objective is to draw attention on a series of factors related to time behaviour within the required parameters and under the criterion mentioned in the current paper. The practical examples analysed for the present study show, through visual characterisation, different visual defects that lead to misfunctioning of the mentioned structures in time. The in–situ investigation was correlated with mathematical models of calculation based on the Wrinkler model, which serves as the primary framework for assessing how the structure responds to stresses and deformations caused by loads encountered during the operation of this type of analysis.

Keywords: anaerobic fermentation, sludge, biogas, water treatment, plant

INTRODUCTION

The long–lasting development of a society requires a constant and reliable water flow, which reaches the necessary water demand per capital in both urban and rural areas, as well as covers the water flow required by the utility services and industrial operations in the area.

Water drawn from surface sources such as rivers, reservoirs or from groundwater sources must be treated to satisfy certain quality parameters to ensure the safety and health of the population and the necessary comfort of the municipality. [1] This is especially important because regulatory compliance is evolving and they permanently need full-time monitoring and improved management. [2]

Wastewater from urban and industrial processes represent a massive negative impact on these water surfaces but also to the climate and energy producing. [3] They need to be purified to the acceptable quality level to ensure ecological preservation of the: soil, groundwaters, rivers, etc.

The treatment of water with respect to its potability, as well as the purification of wastewater is defined as a biochemical process that evolves in time due to the diversity and increase in the pollution. [4] This represents a particularly complex issue which requires large investments of resources and mainly energy consumption. To ensure the effective use of the resources invested, both practical and economic, research must be conducted in multidisciplinary fields, including a high–level engineering design, operating personnel and maintenance of the facility after being put in service. At the same time, the environmental risk and high cost for disposal of the substances used for water treatment represents in general about 30-50% of the total treatment expense. [5]

Romania has a rich history in designing and executing projects of this nature (an example can be seen in Figure1.), with water treatments and purification plants currently operating in some of its largest cities: Iaşi, Cluj, Târgu–Mureş, Timişoara, Arad, Oradea, Constanța, Bucureşti, etc. However, it must be mentioned that there is still a lack in operating water supply and sewage systems in rural areas.

It should also be pointed out that a vast majority of the water purification stations have only two–stages treatment, the first being mechanical and the second one being biological. The new European Directives in the field impose very stern guidelines, including tertiary and quaternary purification stages. Therefore, large efforts and funds are necessary to raise the operational standard of the existing plants to the required criterion.

Figure 1. The Bucharest Municipality Water Purification Center

According to the literature in the field of anaerobic digestion, researchers and engineers are encouraged to study the recycling of the substances used in this process and the correlation with energy. [1], [6], [7].

The fundamental requirements which determine the technological and structural conception of the anaerobic fermentation tanks can be grouped two categories.

The first category is based on functional requirements which determine the technological process and equipment type: hydraulic, mechanic and biological.

The second category focuses on structural requirements such as strength, stability, water tightness and durability, which ensures suitable structural integrity over the course of at least 50 years. [8] This represents the sludge process, still considered the most popular type of biotechnology nowadays, that is composed by a mixture of different compounds among which organic matter, nutrients and substances for fermentation are encountered that have the property to remove pollution from the wastewater.[9] Fermentation takes part of the de-pollution process having the property of changing organic waste into organic compounds. [10], [11], [12].

Concurrently, the efficiency of the fermentation tanks from the technological standpoint is determined by the following requirements:

- ensuring that the stored sludge is at a constant temperature of +35°C all year round. This temperature is specific to the propagation of mesophilic fermentation.
- ensuring the constant mixing and homogenization of the sludge to encourage fermentation and to prevent lithification and sedimentation.
- heating of fresh sludge and ensuring the recycling of the sludge in the context of a constant exploitation at the reservoir level.
- storage of the gases resulted from the fermentation process and design of equipment for the heating of the fresh sludge, as well as to produce electrical energy from burning biogas.
- sludge dehydration and concentration equipment together with the fermented sludge.

Provided that the essential requirements mentioned above are satisfied, then the main scope of the anaerobic fermentation tanks is assured and the mineralization of the sludge via the removal of organic substances and other type of treatments can be fulfilled. [13]

The result of fermentation is the production of biogas that can ensure the energy independence of this treatment stage by creating a cogeneration plant. This is achievable because under normal operating conditions, a fermentation tank would produce a volume of biogas per day equal to the volume of sludge stored in the tank.

The operational safety of the structure of the fermentation tanks, as well as an adequate durability, cannot be ensured without satisfying the fundamental structural requirements: strength, stability, tightness. Meanwhile, the design and shape of the structures of this nature must first and foremost fulfil the functional requirements mentioned above.

Keeping in mind the functional requirements, the structural shape taken by the tank must have axial symmetry, made up of flat and curved plates, for which the ratio between the inner diameter (D_i) and the height (H) of the tank to be between the interval: $1,00 \leq H/D_i \leq 1,50$.

MATERIALS AND METHODS

The most appropriate material for the construction of such a structure is reinforced concrete and prestressed reinforced concrete.

While studying this type of structures in Romania, fermentations tanks with volumes of 1000 m^3, 2000 m^3, 3000 m^3, 4000 m^3 have been built and designed in the form of a truncated cone, composed of a reinforced concrete slab in the form of a circular or truncated conical slab, a curved cylindrical plate made of prestressed reinforced concrete, with ring prestressing and in the direction of the generator and a truncated conical roof plate in the upper part, made of reinforced concrete.

The largest fermentation tanks made in Romania with a capacity of 5 x 8000 m^3 were constructed in an ovoid shape, made up of curved toroidal, conical and cylindrical slabs made of

prestressed reinforced concrete applied along two directions, annular and meridian. The dimensions of this type of tank can be observed in Figure 2, together with the shape and the distances from one point to another.

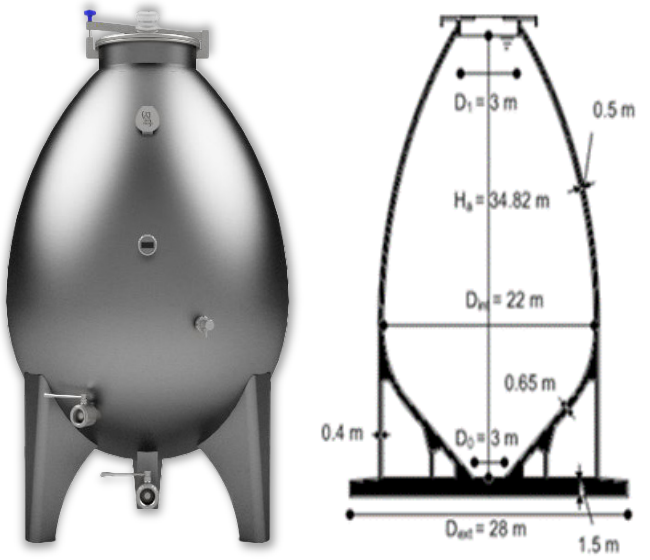


Figure 2. Ovoid shaped fermentation tanks with a capacity of 5 x 8000 m^3

The symmetrical axial shape for fermentation tanks internationally used for this type of structures [4], [8], [14] offers the following advantages: the shape responds very well to functional requirements and from a structural point of view, it ensures an advantageous and safe response in stresses and deformations, especially in the case of prestressed structures in two directions.

Nowadays, modern approaches also allow a different concept for the fermentation tanks (the shape is a cylinder–spherical one) as the solution of getting together both the sludge reservoir and the bio–gas reservoir in the same construction proved to be sustainable in the context of fulfilling almost all the fundamental structural exigencies and those related to electricity supply using fermentation gas. [12]

Figure 3. Fermentation tanks: the sludge reservoir is coupled with the gas reservoir in the same construction

Behaviour of the fermentation tanks over time. A series of factors influence behaviour in time of fermentation tanks, among which one can point out:

- high level of stress of the structures, with the development of a state of spatial stresses, characterized by axial and sliding forces in the median surface of the curved plates, associated with bending moments, shear forces and torsional moments developed in two directions.
- quality of projects and quality assurance during the construction works.
- quality of building materials and implementation of corrosion–proof materials on the inner surface of the tanks.
- corresponding thermal insulation on the outside of the tanks to reduce the efforts induced by the temperature variations.
- proper maintenance of the tank structure, equipment.

Brief overview of the state of stresses and strains in the fermentation tank structure

For the fermentation tank, the determination of the stress and strain state is performed in the elastic linear domain using the analytical method as the solutions of the synthesis equations in the case of bending or circular plates acted upon in their plane are known, respectively the solutions in the bending and membrane theory in the case of cylindrical curved plates. [14], [15].

The soil–structure interaction modelling taken into account for the considerations in this paper is the Wrinkler model for non–cohesive [16] soils and the Pasternak model for cohesive soils, both leading to satisfactory results.

The analytical method of calculation used for the fermentation tanks is applied using the Winkler model and the solutions of the synthesis equations that define the state of stresses and deformations in the bending theory in the case of cylindrical curved plates, as well as the solutions for the circular plates resting on elastic medium using the Winkler model. [16], [17].

From the study of cylindrical curved plates and circular plates elastically supported using the Winkler model, it was possible to define the behaviour indexes of two types of structural elements, whose importance is essential in the actual calculations [3].

The behaviour index (λ_c) of the symmetrically axially stressed cylindrical curved plates was defined with the following expression:

$$\lambda_c = l_c \cdot \frac{\sqrt[4]{3\cdot(1-\mu^2)}}{\sqrt{a\cdot h_c}} \quad (1)$$

where: **a** is the radius of the median surface of the cylindrical curved plate; **h_c** is the thickness of the cylindrical curved plate.

Depending on the value (λ_c), cylindrical curved plates may fall within two categories:

— long cylindrical curved plates having $\lambda_c > 5$ in which the bending effects on one contour are quickly damped and no longer have an influence on the opposite contour;

— short cylindrical curved plates if $\lambda_c \leq 5$ in which the effects on one contour also have an influence on the opposite contour.

The behavior index (λ_c) of circular flat plates resting on an elastic medium has the expression:

$$\lambda_r = a \cdot \sqrt[4]{K/B} \quad (2)$$

where:

≡ a is the outer radius of the circular plate.

≡ K is the coefficient of soil reaction;

≡ $B_r = \frac{E\cdot h_r^3}{12\cdot(1-\mu^2)}$ is the stiffness of the circular plate in bending

≡ h_r is the thickness of the circular plate.

Depending on the value (λ_r) circular plates resting on elastic media can fall within three categories of behaviour, namely:

≡ rigid plates if $\lambda_r \leq 0{,}75$;

≡ semi–rigid plates if $0{,}75 \leq \lambda_r \leq 3$;

≡ flexible tiles if $\lambda_r > 3$.

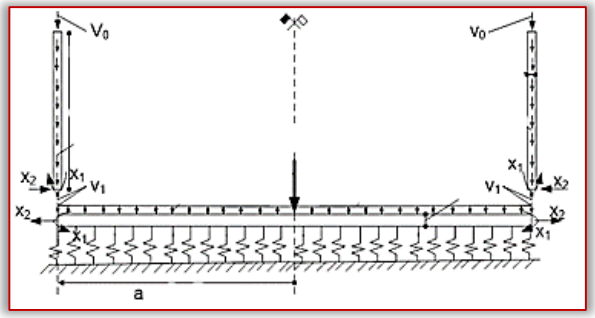
Considering the fact that the cylindrical curved plate has a long cylinder behaviour, and the particular solution of the synthesis equation in the bending theory coincides with the solution of the synthesis equation in the membrane theory and also using the principle of superposition of effects, the calculations were performed using the calculation models presented below.

The calculation model (basic system, Figure 4) was obtained by suppressing the continuity link between the cylindrical curved plate and the circular flat plate of the slab and highlighting the unknown equal and opposite moment (x_1) and shear forces (x_2) on the joint contour.

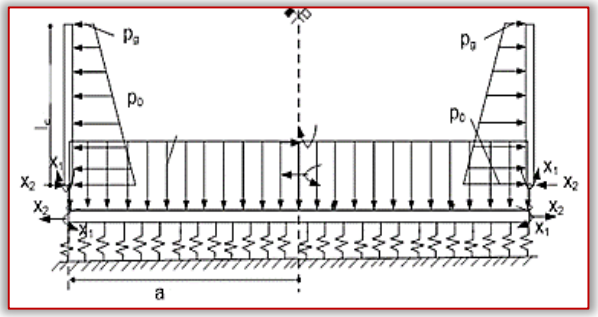
At the same time, in the case studied, at the level of the connection between the wall and the slab plate, there must be equal deformations on both elements at the level of the common contour (Figure 5.b):

— the radial displacement **w** of the cylindrical plate in the lower contour section is equal to the horizontal displacement **u** of the slab plate in the outer contour section;

— the rotation χ_c of the cylindrical plate in the lower contour section is equal to the rotation χ_r of the slab plate in the outer contour section.

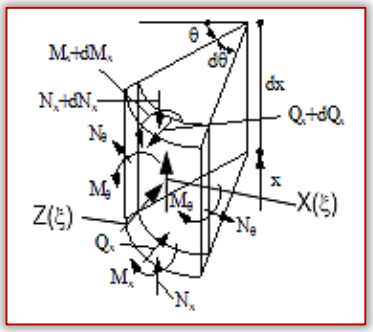


(a)

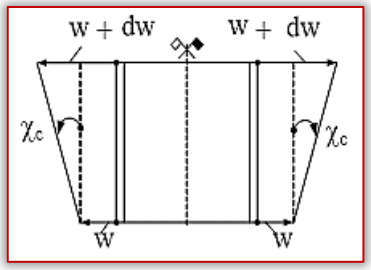


(b)

Figure 4. Calculation model of the fermentation tank in the hypothesis of action a) own weight, respectively b) hydrostatic pressure and internal gas pressure



(a)



(b)

Figure 5. Stress and strain condition in cylindrical curved plate in the convention of positive signs

The synthesis equation of the cylindrical plates subjected to the action of the systems of forces normally applied on the surface of the plate:

$$\frac{d^4w(\xi)}{d\xi^4} + 4\lambda_c^4 w(\xi) = \frac{Z(\xi)\cdot l_c^4}{B_c} \quad (3)$$

with $\xi = x/l_c$, $Z(\xi)$ the component of the external loads in the radial direction, respectively the bending stiffness of the cylindrical plate $B_c =$

$\frac{E \cdot h_c^3}{12 \cdot (1-\mu^2)}$ with E being the longitudinal modulus of elasticity, respectively the Poisson coefficient of the material from which the plate is made.

DISCUSSIONS

While making on–site analysis of fermentation tanks with a service life of 35 to 40 years, some of the following observations were made.

The prestressed concrete structural elements in the form of cylindrical curved slabs in the composition of the cylindro–conical shaped tanks have behaved well over time, with no cracks or other failures.

The reinforced concrete structural elements: truncated cone–shaped slabs and roofs (Figure6.) have registered cracks whose opening have increased over time, above the permissible limit, in the case of these types of works with the dimensions of 0.2 mm.

Figure 6. Cylindrical–conical fermentation tanks with cracked roof dome

The occurrence of cracking (Figure 7) can sometimes be influenced by the quality of the thermal insulation materials, which promote the development of additional stresses from temperature changes. The cracking can also be favoured by the inadequate maintenance of such works.

At the same time, due to inadequate maintenance, the sludge was deposited and cemented in the lower area of the tanks.

Figure 7. Cracking of reinforced concrete elements of fermentation tank

At the vast majority of the tanks, the acid–sulphatic chemical attack (Figure 8) was found due to the fermentation gases and humidity in the upper part of the truncated conical roof tiles, a phenomenon accentuated by the poorer quality of the anti–corrosion protection materials.

Figure 8. Chemical attack on the inner surface

CONCLUSIONS

From the analysis of the behaviour over time of the existing fermentation tanks with an age in operation of 35–40 years, the following recommendations can be deduced for the future:

- the structural shape of future tanks must be axially symmetrical to allow the introduction of prestressing in one direction or in two directions throughout the structure.
- thermal insulation materials must be efficient, to improve both the thermal balance in operation, but also to reduce the effects of temperature variations.
- the corrosion proof protection materials must have high–performance characteristics, both in terms of resistance to chemical attack of the acid–sulphatic type, but also in terms of adhesion to the concrete surface.

Structures with an age in operation of more than 30 years must be rehabilitated by: removal of damaged protections on the entire interior surface; revealing cracks and injecting them; application of new protection materials with high performance both in terms of corrosion proof resistance and physical–mechanical resistances.

Another recommendation is concerning the concept and design of the structures chosen for the fermentation tanks that must be differently chosen according to wastewater content: domestic wastewater mixed with rainwater, industrial wastewater or wastewater from livestock farms and storage capacities.

Depending on the technical condition found in situ and the degree of damage of the reinforced concrete elements (truncated conical roof dome), possible rehabilitation and consolidation solutions can be analysed using carbon fibre fabrics, additive mortars and special resins with resistance to corrosive actions of the acid–sulphatic type.

However, the rehabilitation–consolidation solutions adopted must not significantly modify the thickness of the element so as not to produce additional stresses from temperature variations, given that they are proportional to both the value of temperature variations and the value of axial stiffness and bending stiffness.
The adhesion of the reinforcing materials to the existing concrete structure must also be ensured where the unit adhesion force must be greater than 2000 kN/m² [3]. At the same time, the cleaning of the existing concrete surface must be carried out with pressurized water.

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ASSESSMENT AND EVALUATION OF THE SOUND QUALITY OF HOME APPLIANCES

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Abstract: Currently, manufacturers of electrical household appliances that emit noise are trying to reduce the noise of these appliances for several reasons. For some product groups, manufacturers must declare acoustic performance levels according to accepted standards. This fact is perhaps the most important driving force for performing anti-noise modifications on household appliances. However, the quantity of the emitted sound is not important in every case, but also the quality of the sound, i.e. customer perception of sound. The scientific discipline of psychoacoustics deals with sound quality, which brings a new perspective to the evaluation of the acoustic quality of household appliances.
Keywords: psychoacoustics, binaural measurement, valuation

INTRODUCTION

Psychoacoustics, or psychological acoustics is an interdisciplinary scientific discipline dealing with human perception of sound, i.e. how the brain processes sound. Sound perception is a very detailed and complex process. The task of psychoacoustics is to observe and investigate the impact of various sounds on a person and his psyche [1].

Psychoacoustics has found its application primarily in the automotive and aviation industries in the design of cabin and cockpit interiors, but also in the development of household appliances and their optimization, with the goal being that the sound of the given appliance is not unpleasant for the consumer. Another application is in binaural measurements, sound diagnostics and quality control.

PSYCHOACOUSTICS AND SOUND QUALITY

The term psychoacoustics has been better known for the last 25 years. Sound has many objectively measurable properties, but these may not give a good picture of what a person perceives by hearing. Air is a continuous medium, so its molecules can theoretically transmit any mixture of frequencies, each with a unique amplitude and phase. However, the fact is that not everything is important to the human ear and therefore does not need to be recorded. The perception of sounds is, for a non-negligible part, also judged by people according to immediate facts and sound-induced associations (emotions).

In recent years, much effort has been devoted to describing the quality of individual sound stimuli or phenomena, such as warning signals in cars.

Today, especially in the automotive industry, the trend of increasing the "sound quality of products" is strongly preferred, the goal of which, based on the wishes and evaluations of customers, is to assign sounds to individual products that would connect them with important sales criteria such as luxury, robustness, performance, etc. A similar trend is currently being enforced in the household appliance industry [2].

OBJECTIVE ASSESSMENT METHODS

Objective methods of evaluating the psychoacoustic quality of sounds are based on the evaluation of binaural recordings made with special measuring devices called artificial heads and subsequent software evaluation of the sound signal with subsequent determination of individual psychoacoustic parameters (sharpness, roughness, fluctuation, tonality, etc.) [3].

Sound recordings and recordings captured by classical microphones are not suitable for aurally accurate assessment of the acoustic environment and noise sources, because essential acoustic information such as spatial and directional distribution of noise sources, masking effects, selective hearing and others are lost. A person can locate noise sources three-dimensionally, in the horizontal and vertical planes.

Localization is performed automatically based on time delays and different levels of acoustic signals reaching both ears. The outer ear causes direction-dependent filtering of sound signals. The result of this filtering is dispersion and thus modification of sound waves - reflection, bending, and attenuation. The geometry, anatomy of the head and shoulders and the auricle itself are important. Based on the ability of the human hearing apparatus to localize noise sources, a person can perceive individual

noise sources selectively from the overall noise and background noise [4].

Binaural perception cannot be simulated by simply using two microphones as substitutes for ears. Such recordings can only be used after applying an acoustic filter that takes into account the characteristics and geometry of the human head, ears and shoulders. The processing of acoustic signals by hearing and apparatus is complex and provides the receiver with a complete and holistic impression of the sound event.

The sound field is influenced by the head, shoulders and ears. The artificial head is a simulation of the human head and shoulders, not only concerning the shape but also the surface, the properties of which correspond to the properties of human skin. Also, the shape of the ears of the artificial head corresponds to the anatomy of the real human ear. Thanks to this form, the artificial head is allowed to modify the sound field just like in reality, so it can recognize differences just like the human ear [5, 6].

He has microphones in his ears, through which sound is recorded. The artificial head enables the recording of sounds as a person would hear them if he were in the place where the artificial head is located at the time of measurement.

Currently, several devices from different manufacturers are available on the market, which are intended for the measurement of acoustic and psychoacoustic sound parameters. These devices are generally called artificial heads. They have the shape of a human head with a partial torso and have a pair of microphones placed in their ears. The material of these devices has similar acoustic properties to human skin. Since these devices have a pair of microphones placed in the ears, they are also called binaural measuring devices. Binaural measuring devices from different producers are shown in Figure 1 – Figure 4.

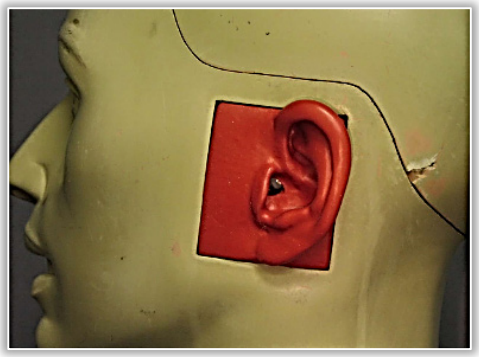

Figure 1. Artificial head – KEMAR [9]

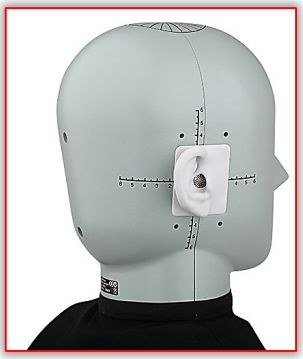

Figure 2. Artificial head - Brüel & Kjær [11]

Figure 3. Artificial head – Head Acoustics [8]

Figure 4. Artificial head – Neumann KU 100 [12]

SUBJECTIVE ASSESSMENT METHODS

Subjective assessment methods are based on getting people's reactions or customers to individual sounds. Such evaluation is carried out with a selected group of people, to whom the evaluated sounds are played. Respondents then fill out a questionnaire with their opinion on these sounds. The questionnaire can take different forms, where people evaluate these sounds on a numerical scale, assign certain properties to the sounds, or semantic differential methods are often used. By subsequent processing of the results from these questionnaires, we can assess the quality of individual sounds from the point of view of perception by ordinary people. However, the entire process of such testing is very demanding and lengthy and requires rigorous preparation.

The main problem of evaluation of sound quality by listeners is the dependence on various

circumstances, for example, expectations and the emotional state of the listeners. These influences can only be eliminated by appropriate selection and training of respondents. It is very important to choose an appropriate method of statistical processing of the data obtained from the questionnaires to avoid distortion in the evaluation of the obtained data.

In general, we can say that subjective evaluation by respondents allows assessment and determination of the quality of products based on their sounds, i.e. determination of better and worse sounds from the point of view of customer perception. By identifying the best and worst products in terms of sound quality, it is then possible to design the product to minimize unpleasant sounds.

Manufacturers are often motivated to address the issue of sound quality if they are exposed to customer complaints if the product emits disturbing sounds.

The evaluation of sound quality by respondents can also be used in cases of achieving the desired sound characteristics. If we want to make the sound of the product more powerful, more powerful, stable, etc [6].

Specialized software applications are currently available on the market for sound evaluation by respondents, which optimizes the entire testing process.

COMPARISON OF OBJECTIVE AND SUBJECTIVE ASSESSMENT METHODS

As we mentioned above, both objective and subjective methods of assessing sound quality have their advantages and disadvantages.

Subjective methods are time-consuming and lengthy to prepare and implement, and the main problem is the pitfalls associated with respondents. However, some knowledge about the quality of sounds cannot be obtained other than through questionnaire methods. These methods cannot be used for the evaluation of sounds with a longer duration, e.g. the washing cycle in the washing machine takes more than 2 hours. It is necessary to prepare representative samples of sounds with a duration of only a few seconds, but the entire evaluation process is partially distorted since it does not evaluate the entire cycle [9].

Objective methods are less time-consuming and do not require lengthy preparation. Based on the results of determining the values of individual psychoacoustic variables, we cannot unequivocally claim that sound with lower values of sharpness, roughness, tonality, etc. is better for the customer. And for several reasons. There are also several issues to be resolved. One of them is the correct selection of psychoacoustic parameters for the given product groups, based on which the sound quality assessment will be carried out. Determining the weight and importance of selected psychoacoustic parameters is also crucial. These factors will vary for each product group based on the differences in their sounds.

Objective assessment methods are implemented through binaural measuring devices - artificial heads. However, these measuring devices are also suitable for subjective methods. It is advisable to capture the sounds that will be played to the respondents using an artificial head and then reproduce the recordings obtained in this way through the dynamic headphones of the respondents. Respondents thus get a real feeling from the recorded sound.

Both methods require complex preparation and it is necessary to focus on individual partial tasks:

- place of measurement and recording,
- preparation of the measurement and recording process,
- editing audio recordings,
- creating test sounds,
- activities related to creating questionnaires,
- implementation of tests with respondents
- evaluation of questionnaires using appropriate statistical methods.

CONCLUSIONS

Basic subjective and objective methods of sound quality evaluation are described in the article. It must be emphasized that even objective methods are ultimately burdened with a certain degree of subjectivity since the selection of individual psychoacoustic quantities and determination of their weights is necessary for the evaluation. Determining the values of individual psychoacoustic values of different sounds is an objective process, but this does not guarantee that the given sound will be more pleasant for the customer or less annoying, as customer expectations and demands for the sounds emitted by individual products are different. For these stated reasons, it is advisable to look for a connection between these two methods to achieve real results in evaluating the psychoacoustic quality of the sounds emitted by individual product groups. In practice, it will be about the correlation of experimental measurements and the determination of psychoacoustic parameters with the results of

questionnaire assessments for the same sounds. Based on this correlation, a mathematical model will be proposed that would be able to evaluate the psychoacoustic quality of sounds only based on measurements with a binaural measuring technique followed by the determination of psychoacoustic parameters. The input variables of this model would be the values of individual psychoacoustic variables and the results of correlation with the questionnaire method, based on which the selection and importance of individual psychoacoustic parameters would be determined, respectively, other parameters. However, such a model would not be generally applicable for all products, but for a given product group.

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APPLICATION OF RENEWABLE ENERGY SOURCES IN TRAFFIC – BUS STATION AS A GREEN ENERGY ISLAND

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Abstract: The use of renewable energy sources in urban areas is becoming more common. Our design solution offers the possibility of supplying energy to fully electric buses at adapted stops, especially at the final stations (turning points). Adjusting the roof of the station enables the use of solar energy and wind energy with the possible expansion of the application of the road structure in order to increase energy capacities (protective fence as a linear energy block and sound protection of the settlement from traffic as an energy island). In addition to the good fit of the wind generator and the photovoltaic panel, their mutual harmony increases the overall efficiency of the entire system. The convenience of the turnpike is due to the longer stay of buses compared to other stops, so there is enough time to recharge the batteries, and at the same time, there is less influence of neighbouring buildings on the station installations on the periphery, so the use of renewable energy sources is better.
Keywords: renewable energy, electric bus charger, hybrid electric vehicle

INTRODUCTION

Many countries have green transport or green lines. The Nederland has been supplying the railways with renewable energy sources for a decade. This is an attempt to bring the production and consumption of energy as close as possible, and at the same time to point out that urban areas also have untapped potential.

The paper wants to point out solutions that can improve and facilitate the operations of carriers in the city. The necessary structure for the formation of e–bus chargers can be completely concentrated at bus stations, but road infrastructure can be also used as support (solar protective fence with wind generator, as well as a protective wall against traffic noise as energy support).

At the same time, they want to use all the developed potential for automatic connection and charging of the accumulators located in the bus (pantograph or increasingly successful wireless system for charging large batteries).

BUS STOP AS GREEN ENERGY ISLAND

The most common design of electric buses is with the accumulation of energy in electric form with the use of suitable high–capacity accumulators. It should be borne in mind that this category of vehicles is divided into BEV, PHEV and HEV electric vehicles as shown in Figure 1.

Regardless of which category of vehicles we want to support in the form of charging on the road route, we want it to be based on the use of renewable energy sources. Due to the significant power of such a charging system, a large active photovoltaic area supported by a hybrid solution with wind generators is required. The most favorable location for placing the equipment is at the central bus station, where there is the largest roof area on which the panned equipment can be placed. The second option is usually offered by turnpikes or the end stations of certain routes due to a slightly longer stay compared to standard stops.

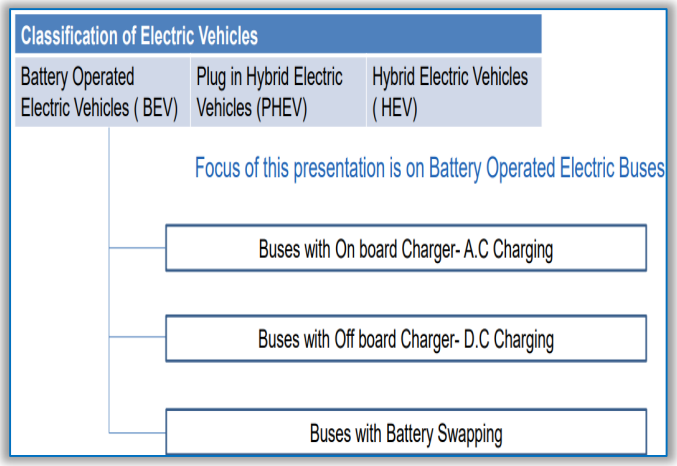


Figure 1. Battery operated Electric Buses

In this paper, three options are considered:

1. Constant charging of the station's energy wall from renewable energy sources with fast charging of the bus battery when it is in the station,
2. Charging of mobile replacement batteries where time does not limit the charging time but the battery replacement time (optional – battery trailer – Figure 2 [3]).
3. Using the trolley bus contact network to supplement electric buses.

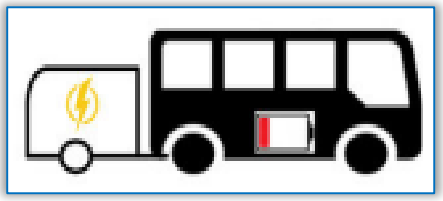


Figure 2. Accumulation and replenishment system in the form of a trailer

Modern buildings have a small slope of the roof, which is not the most favorable position either for using solar energy or for using wind energy. Table 1 shows how the slope of the roof affects the acceleration of air masses at its highest point – the ridge. Correction of the slope of the roof can be done with air deflectors, which also serve as photovoltaic panels and directly convert the energy of solar radiation into electricity.

Table 1. Wind gain depending on the slope of the roof

Roof slope	0^0	8^0	15^0	30^0	45^0	60^0
Wind acceleration	X 1.0	X 1.1	X 1.2	X 1.5	X 2.2	X 1.3

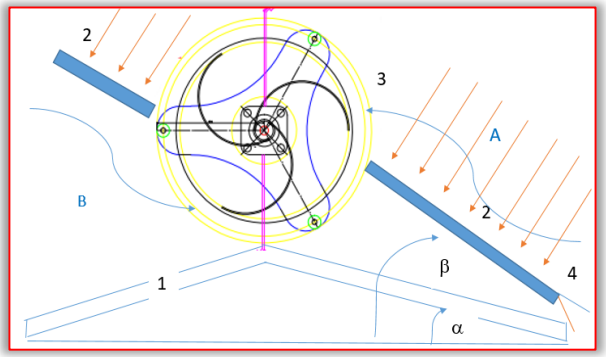


Figure 3. Hybrid power station – The roof of the bus stop
1–The roof of the bus stop; 2–Photovoltic cell; 3–Wind turbine [5]; 4–Blinds
A, B – Different wind directions; α– Roof slope; β – Photocell slope

The photovoltaic panel (Figure 3) directs and accelerates the air (table 1) increasing the efficiency of the wind turbine. Apart from directing the wind towards the drive part of the turbine, doubling the speed increases the power 8 times [equation 1]. A higher tilt of the fixed panel gives a higher utilization of the photovoltaic panel at our latitude.

$$P_{wind} = \frac{E_{kin}}{\Delta t} = Cp\frac{\Delta V \rho v^2}{2\Delta t} = Cp\frac{\rho A v^3}{2} \quad \text{[eq 1]}$$

$$C_p = \frac{2P_{wind}}{\rho A v^3} \quad \text{[eq2]}$$

v – wind speed, ρ – air density, A – covered area, Pwind – wind power, Cp – power factor

This study aims to optimize the shape of Savonius wind rotor to achieve highest C_p *[7]*.

The blades of the wind turbine are coated with high–efficiency photovoltaic foil to form an additional photovoltaic panel.

The entire structure forms a large photovoltaic panel with a wind–generator. If we use a spiral turbine, we use wind energy even when it blows sideways in relation to the object. Wind speed is measured with a Testo anemometer – Figure 4.

Figure 4. Testo Anemometer

E – bus supply system

With new technical solutions, more options enable the automatic connection of the E–bus and the powerful battery charger [11]:

— E–Bus stationary charging (wire connection – pantograph). ABB pantograph e–bus charging system [2] is shown in Figure 5. Different pantograph systems for e–bus – Figure 6.

Figure 5. ABB pantograph e–bus charging system

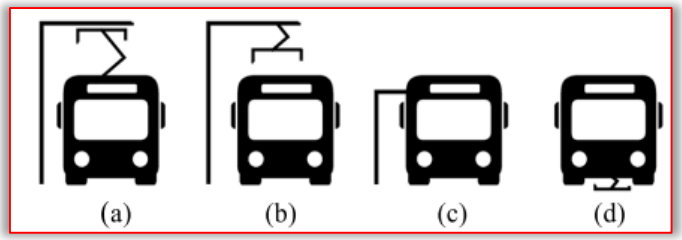


Figure 6. Different pantograph connection models and real configuration: (a) roof–mounted (b) inverted (c) horizontal (d) underbody. [13]

— E–Bus charging in motion (partial trolley bus) [9] – as it shown in Figure 7:

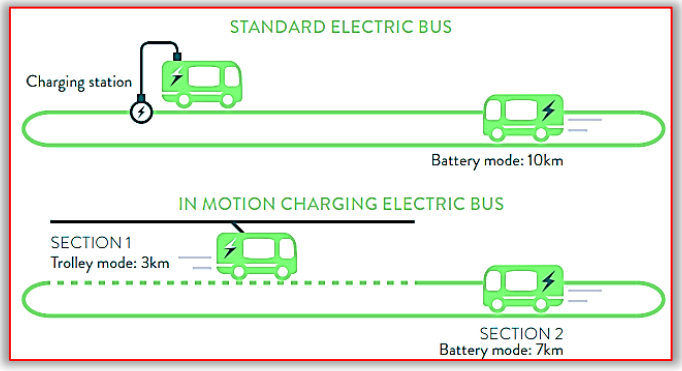


Figure 7. Stationary and charging in motion (wire option)

a) Possible bus connection on the tram's power line

b) Possible line supply from the "Green bus charger" [8]

≡ Green bus charger supplied from the turning point – station

≡ Online section supply from "Power WALL" – protection against traffic noise

≡ Online section supply from "Fence power structure" – off–road protective fence

≡ Energy islands in traffic – hybrid system photovoltaic panel and wind generator

— E–Bus stationary charging (wireless charging) [13],

— E–Bus charging in motion (wireless charging in motion) – Figure 8.

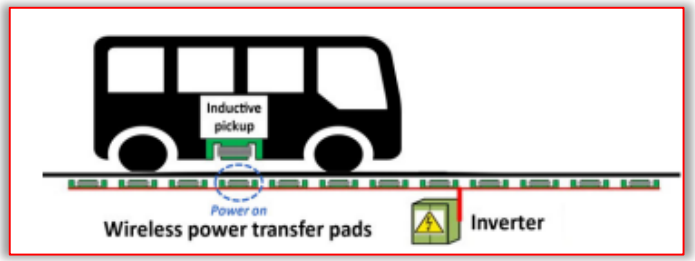


Figure 8. Wireless charging in motion

Wireless charging

Based on operating Techniques EVWCS (Electric Vehicle Wireless Charging System) [15] can be classified into four types:

— Capacitive Wireless Charging System (CWCS)

— Permanent Magnetic Gear Wireless Charging System (PMWC)

— Inductive Wireless Charging System (IWC) – Figure 9.

— Resonant Inductive Wireless Charging System (RIWC)

By using WCS EV's travelling range could be improved with the continuous charging of its battery while driving on roadways and highways. It reduces the need for large energy storage which further reduce the weight of the vehicle.

Position of Hybrid panels + Wind generators

When using hybrid panels to charge e–bus batteries, many options are usually provided:

≡ Installation of hybrid panels on administrative buildings and garages of the utility company in charge of transportation.

≡ Installation of hybrid panels on the main bus station and usually a large canopy.

≡ Installation of hybrid panels at the final bus stops due to longer bus stops for recharging – Figure 9. Savonius turbine is optimised for this purpose [6].

Figure 9. Photovoltaic canopy (bus station) with wind generators (turbine is a photovoltaic panel, too).

≡ Installation of a hybrid system (solar panel + wind generator) on protective fences against traffic noise.

≡ Installation of hybrid system components on the roadside guardrail – Figure 10.

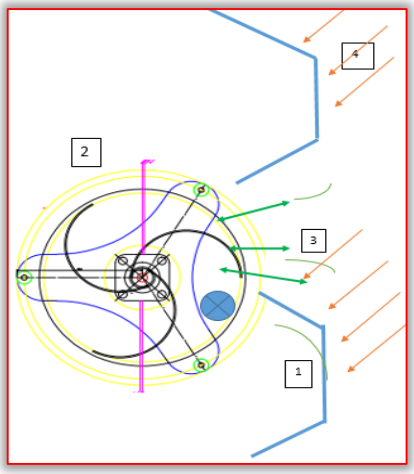


Figure 10. Roadside guardrail E– Wall

1–Roadside guardrail – photovoltaic panel, wind diverter, 2–Helical Savonius turbine [4]; 3–Alternating movement of air traffic masses; 4–The sun's rays are converted into electricity on the panel.

The system converts the energy of the sun, the energy of the wind and the energy of air masses of traffic into electrical energy.

≡ Installation of photovoltaic components and wind generators on traffic islands.

≡ Installation of photovoltaic components and wind generators on a typical bus station.

ANALYSIS OF WIND GENERATOR OPERATION (MODIFIED SAVONIUS)

The energy can be collected with the help of a helical Savonius turbine exposed to the wind flow that is accelerated due to the slope of the roof. Such wind turbines is more efficient and economical compare to conventional which are based upon natural wind energy.

Our turbine type is Mini: This type of wind turbine can produce electricity from 250 W to 1400 W. The standard of classification of wind turbines was regulated in IEC 61400 for large, medium and small wind turbines.

The performance improvement of a helical Savonius rotor is studied by using three dimensions CFD model & experimentally in the papers. Researches are carried out to study the influence of blade number, overlap ratio, helical angle, no. of stage and aspect ratio on the performance of helical Savonius rotors [17].

The Savonius turbine is usually used as a vertical shaft turbine [1], but here it is used with the shaft in a horizontal position. If we use a helical turbine, we use wind energy even when it blows sideways in relation to the object. Helical Savonius turbine with some variations is shown on Figure 11.

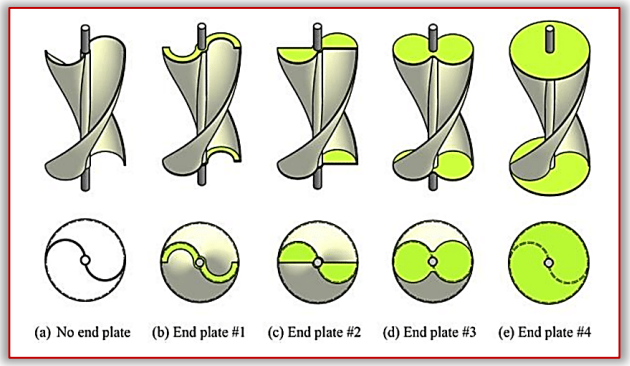
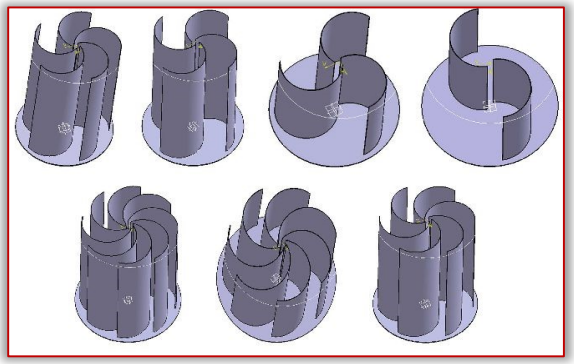


Figure 11. (a) Helical Savonius rotors at different twist angles



(b) Helical Savonius rotors with different number of blades

Advantages of usage this type of turbine:

— High output even at a low wind speed of 2.8 m/s (10 km/h)
— Strong wind gusts are easily managed and eliminates the need for complex adjustable blades
— The system does not require a shutdown even during a storm (other turbines are at shut down at wind speeds in excess of 24–27 m/s)
— Practically silent operation
— Constant uninterrupted output in high winds
— The system is robust, shows little wear, it is maintenance–free, has low operating costs and the mechanical structure is not complex
— Use of permanent magnet generators with long life and low–speed
— High uptime
— Extremely low starting torque and therefore good electromechanical conversion of the kinetic energy
— No special foundations are required, a simple bracing is in most cases sufficient. Easy installation on the ground, roof and wall mounted
— The use of advanced fiber composites ensures an ultra–lightweight construction with maximum strength and UV resistance and therefore high efficiencies
— Modular and highly flexible construction (equal part–modular principle). Individual components can be replaced at any time. A power increase via retrofitting is possible at any time
— The helical structure provides the wind with sufficient engagement surface at all times and at every angle of rotation
— Ultra–modern, rational, and cost–effective production
— Performance optimization using the latest power electronics
— Uniform rotary motion
— No mechanical losses, since the system operates without gearing (direct transmission)
— Extremely profitable due to low cost, easy installation, and maintenance–free operation with a virtually unlimited lifetime
— Excellent aerodynamic efficiency
— Superior optical effect
— Can be used as an advertising medium

ANALYSIS OF SOLAR PANEL PERFORMANCE

The economic viability of a power plant to harness solar energy mostly depends on the efficiency of solar panels. Investigations over the years show that solar panel efficiency significantly depends on the different meteorological parameters [16]. Therefore, there is an imminent need for a correlation explaining the relations between efficiency and different meteorological parameters. In this study, an effort has been made to analyze the effects of various meteorological parameters on efficiency and subsequently propose a correlation between them.

Figure 12 shows the measurement related to the power obtained from the solar panel, depending on the slope of the same. During most of the year, the maximum is observed at an angle between 35 and 45 degrees.

As we have covered before, the angle of the sun's rays change throughout the year, so the 'perfect angle' will change throughout the year [12]. The experimental solar panel efficiency was

then determined by using the methodology listed below.

$$\eta_p = P_p/(A_p x I_p) \quad \text{[eq 3]}$$

Here, η_p is the solar panel efficiency, P_p is the power, A_p is the surface area of the panel, and I_p is the solar intensity. Here, the power of the solar panel is the product of voltage and current, which are measured with the help of a multimeter. Likewise, the solar intensity is measured with the help of a solar power meter – Figure 13.

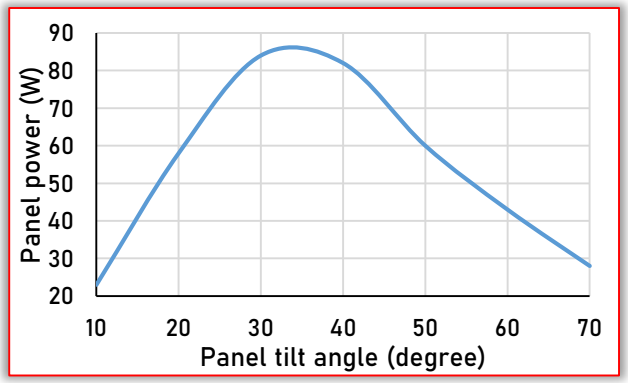


Figure 12. The influence of slope on the usefulness of the panel

Figure 13. Solar power meter TMP206

ACCUMULATION OF ENERGY

Usually, the contributions of energy from renewable sources are not aigned with the current needs of consumers, so the possibility of accumulating energy is of grate importance. The same energy can be used to recharge the bus battery. Charging the statio'n energy wall is continuous, and bus batteries are quickly and temporarily charged. It is convinient that with the new technology the charging time is getting shorter and shorter (15 minutes), but the problem is connecting a high–power charger. Charging from the energy wall does not require a large installation power that complements the support system when contributions from renewable energy sources are small.

The accumulation of energy from hybrid systems [7] reduces the load on the electrical network and enables the use of energy near the consumer, which reduces losses in energy transmission.

Regardless of the practical use of the storage system [10], we must be aware that we have certain losses when filling and emptying the storage. It should be borne in mind that the costs of accumulation change depending on the type of accumulation Figure 14.

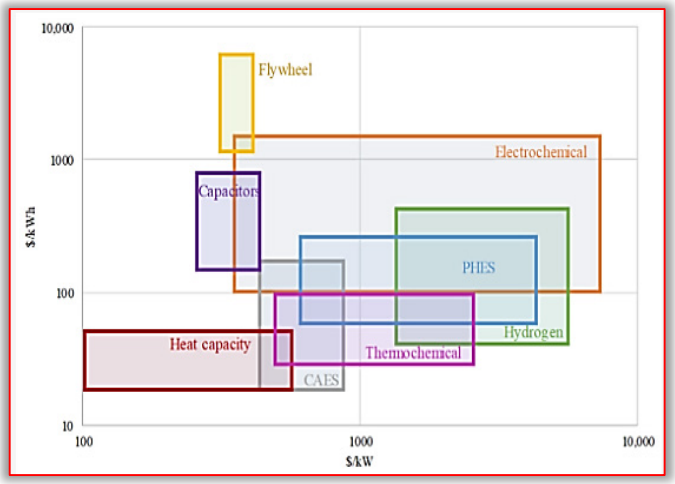


Figure 14. Cost of energy accumulation system

When accumulating energy, we must include all losses that occur during charging, during energy conservation and during discharge [14]. The attached Figure 15 shows typical places where losses occur during the accumulation and subsequent use of the accumulated energy.

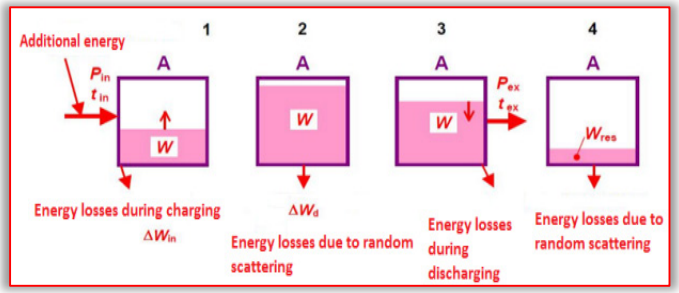


Figure 15. The state of the energy accumulator (A) (simplified)
1 – Reception of energy, 2 – Readiness state,
3 – Energy supply, 4 – Discharged state,

where Pin is the power input, Pex – output power, Tin – duration of charging, Tex – duration of energy release, 14 W is the accumulated energy Pin – power consumption, Pex – output power, Tin – duration, Wres is the residual energy, Win – loss when charging, Wex – losses in the energy release, Wd – energy loss due to random scattering The accumulation of energy is usually understood as a purposeful action.

The result is shown, for a hybrid system whose designed power does not exceed 10kW. Here the charactteristic is shown (Figure 16) for the spring, summer and early autumn periods.

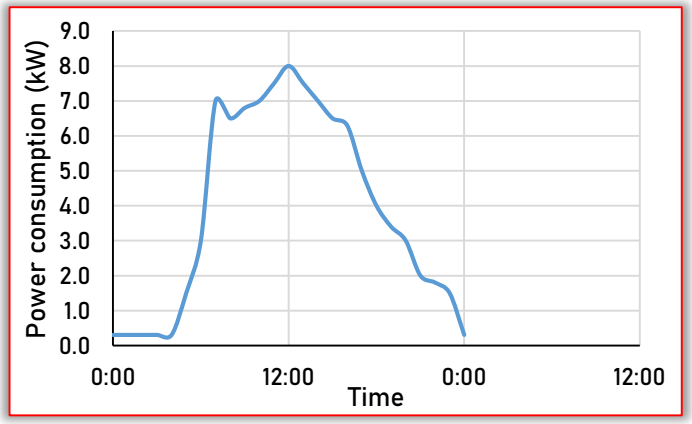


Figure 16. Daily distribution of electricity, consumption for typical activities (schedule display + charging)

The dynamics of using the battery charging system for electric buses depends on the dynamics of the traffic on the selected bus line.

CONCLUSION

The hybrid system mentioned in this paper harmonizes the operation of the solar system with the wind generator, but with complete harmony and mutual support, which gives more than double rather mutually independent systems.

An adapted bus station can be used to charge e–buses and in the option when we have a stationary system, when the station's batteries are continuously charged, and then the bus batteries are charged in a short period of time. Another option is for the selected station to supply a limited network that allows e–buses to be charged in motion. This system can be used when there is short bus stop at the final stop, the turnpike.

In case the option of using green hydrogen [20] is chosen in the future, an electrolyzer can be additionally used to convert the obtained electricity into hydrogen.

The support for the e–bus battery charging system can be provided by the infrastructure located near the station (roadside protective fence converted into an active hybrid system, sound wall for protection against traffic noise converted into a charging system, use of traffic islands with additional support).

The system can be adapted according to the choice of future drive in public transport.

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LOGISTICS TRENDS THAT ARE BECOMING MORE PROMINENT

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Abstract: Following logistics trends is crucial for several reasons in today's evolving business environment. Staying current with logistics trends is essential for businesses looking to remain competitive, efficient, and adaptable in a rapidly changing business landscape. It enables them to make informed decisions, reduce costs, improve customer service, and adapt to the latest technologies and regulatory requirements. While new logistics trends can bring about various benefits, they also come with potential risks and challenges. To mitigate these risks, businesses should conduct thorough risk assessments, develop contingency plans, invest in employee training, and stay updated on relevant regulations. They should also consider the long–term consequences and impacts on their supply chain and customers when embracing new logistics trends. Careful planning and evaluation are essential to successfully navigate the potential pitfalls associated with emerging logistics practices and technologies.
Keywords: internal logistics, elastic logistics, automation, digitalization, technology effects

INTRODUCTION

Logistics has always been open to the opportunities presented by new technologies, as the essence of the field lies in responding to the effects of a constantly changing environment. This process has particularly accelerated with the demand for the extensive application of the so–called "elastic logistics trend".

This approach allows companies in the supply chain to adapt to changes in the business environment and respond to fluctuations in market demand, disruptions in the procurement chain, or changes in workforce planning. Furthermore, this responsiveness enables the minimization of inventory shortages and overstocking.

Elastic logistics is the ability to be flexible in responding to the changing requirements of the supply chain by scaling warehouse resources so that they are efficient when demand peaks and bear no excessive costs in periods with fewer shipping orders. [1]

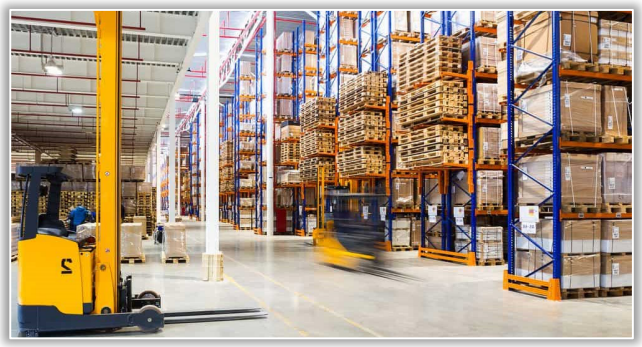

Figure 1. Logistics

Due to the significant technological advancements that have affected all areas of logistics in the past decade, technological elements play a crucial role in the further development of logistics, providing various efficiency and financial benefits.

As elastic logistics requires different tools at various points in the supply chain, it is essential to narrow down the focus in this chapter to technological elements within the company. Examples include new storage systems, material handling equipment, information processing tools, and theories that have emerged and integrated into logistics systems. In warehouses, automation in physical operations is the new direction, often linked to flexibility. The more precise, faster, and efficient the physical operations (packaging, repackaging, stacking, material handling, sorting, loading, and unloading, identification), the more effective the warehouse management.

The growth of flexible logistics raises the need for businesses to become more agile in their operations and processes. Undoubtedly, introducing technologies such as automation and the widespread application of digital technology will impact the future of logistics. While the implementation of these may initially seem daunting, with proper planning, it can become a revolutionary strategy for your business.

Therefore, the ability to quickly and efficiently respond to the continuously changing market environment can be achieved through the automation of logistics systems within the company and the combined application of digital technology tools. In the further sections of this chapter, we will focus on these (internal logistics) tools.

PHYSICAL TOOLS – AUTOMATION

Warehouses are important components of most supply chains. In terms of cost, they represent approximately 20 per cent of total logistics costs. [2]

Warehouse automation is a defining phenomenon of Industry 4.0, essentially encompassing technologies that enhance the efficiency of logistics processes. Automation tools, robots, self–driving forklifts, or various software solutions support the two functions of storage and material handling in warehouses.

Robotics is the intersection of science, engineering, and technology that produces machines called robots, designed to replicate or replace human activities. The term originates from the Czech word "robota", meaning "forced labor", and has been used for about 100 years.

Figure 2. Warehouse automation

The history of robotics spans several centuries, but its most significant developments occurred after World War II, particularly in the 1950s, when the first industrial robots appeared in the automotive industry (performing tasks such as welding and painting). With the advancement of computers and electronics, more complex, programmable robots were created.

Automation is quite common in large warehouses, especially in transportation/sorting and automated storage and retrieval systems, as each of these types of equipment can be found in more than two–thirds of large warehouses. [3]

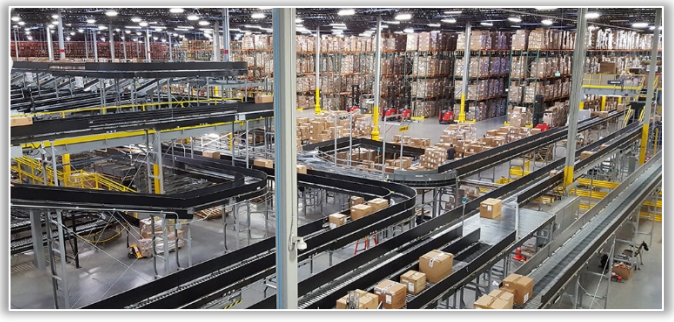

Figure 3. Automation

The simplest and most common form of automation is the use of conveyor belts. Besides making the warehouse area more efficient with conveyor systems, it's essential to note that it provides a much safer material handling option for goods. Nowadays, the use of robots is an integral part of modern logistics. They can handle picking and packing processes within warehouses. In both cases, they operate with the assistance of various cameras, sensors, and algorithms.

Packaging is typically a monotonous task, and using robots is advisable, especially when uniform packaging is required, as they can be programmed for the entire packaging process. Automation is a long–term investment, primarily suitable for economic environments where labor is more expensive. When establishing an automated environment, consideration must be given to providing proper training in transforming workplaces and employing skilled individuals to perform maintenance and repair processes. [4]

Today, we witness continuous development as artificial intelligence and machine learning are integrated. Advanced autonomous vehicles (not only for roads but also for industrial use) are becoming a part of our everyday lives.

Automated Guided Vehicles (AGV)

Automated Guided Vehicles (AGV), or automated guided vehicles, are material handling devices designed to assist in material flow and order fulfillment within manufacturing facilities and warehouses.

AGVs are automated vehicles capable of moving and navigating autonomously along predetermined routes or maps. These intelligent vehicles find applications in various industrial settings.

Figure 4. Automated Guided Vehicles (AGV)

AGVs are often employed in material handling tasks, such as warehouses and logistics centers. These devices can efficiently transport pallets, boxes, or other loads from one point to another, seamlessly integrating into manufacturing processes.

Equipped with sensors and cameras, these devices help determine their routes and avoid obstacles. Their use contributes to reducing

reliance on human labor, optimizing processes, and increasing productivity.

Autonomous Mobile Robot (AMR)

The abbreviation "AMR" comes from the expression "Autonomous Mobile Robot", which in Hungarian means "Autonóm Mobil Robot." AMRs are autonomous vehicles capable of navigating their environment independently, without the need for external guidance or control. Autonomous robots can navigate around obstacles and efficiently optimize routes. These devices adapt flexibly to changing environments and can be easily integrated into production lines.

Figure 5. Autonomous Mobile Robot (AMR)

AMRs are typically equipped with sensors, cameras, and other detectors to perceive their surroundings and adapt to their habitat. Autonomous operation allows them to dynamically adjust their routes according to current conditions, thereby increasing efficiency and adaptability.

Automated Storage and Retrieval System (AS/RS)

The "Automated Storage and Retrieval System" (AS/RS) is an automated storage and retrieval system that employs robots and machinery to efficiently and automatically manage warehouses. The goal of AS/RS systems is to maximize warehouse space utilization, minimize stocking time, and accurately pick goods during the retrieval process.

Figure 6. Automated Storage and Retrieval System" (AS/RS)

These systems typically consist of high shelves or storage units served by robots or stacker cranes. AS/RS systems can be single–deep, where goods are stored in a single row, or multi–deep, where goods are stored in multiple rows or levels. AS/RS systems significantly contribute to the more efficient and automated operation of warehouses. They reduce the need for human labor, increase accuracy, and expedite warehouse processes.

Drones

Although the use of drones initially promised many advantages in all areas of logistics, it has become certain that the limitations of the technology and the lack of regulations restrict the widespread adoption of drones. However, in logistics, they are increasingly being used, for example, for various tasks in warehouses. Drones can help optimize logistics and storage processes, such as inventory checks and counting. Drones can traverse the warehouse, capturing images or videos of the inventory with their cameras.

Another application is the surveying of warehouse layouts, where drones create maps of the warehouse area, aiding in layout optimization and the development of more efficient storage strategies. The use of drones can be beneficial in increasing the efficiency and accuracy of warehouses, serving as complementary tools to assist human labor.

Figure 7. Drones

Aerial drones can optimize the inventory processes in warehouses. They can scan through the inventory much faster than a human, providing accurate data instantly to the warehouse inventory management software. Drones do not occupy valuable space, and there is no need for markers or fixed paths that could impede traffic in the warehouse.

Summary of advantages and disadvantages

It is important to understand that automation itself is not a bad thing, but its excessive extent or improper application can cause problems. Although the introduction of robotics and advanced technologies is extremely costly, the investment can pay off within a few years.

The use of robots comes with many advantages:

— reduction of human errors and warehouse costs,
— good adaptability,

— guaranteed availability,
— dangerous tasks no longer need to be performed by humans,
— potential for significant long–term profit,
— faster and more accurate execution of processes.

However, excessive warehouse automation can carry some challenges and potential dangers. Some potential risks and challenges include:

— job losses,
— investment costs,
— system errors and cybersecurity risks,
— unilateral dependence on technology.

While automation can make warehouse operations more efficient, it may also mean less need for a different type of human workforce. This underscores the importance of skills and retraining needs, as the rise of automation may require new skills from workers. Optimized and well–planned automation, however, can contribute to the efficiency, competitiveness, and innovation of companies. The key is to apply automation in an appropriate and balanced manner, taking into account the importance of human labor and potential societal impacts.

DIGITAL TOOLS – DIGITIZATION

The purpose of digitization is to transform key business activities, business processes, existing organizational structures, existing management concepts, and ultimately the products produced by the company. [5] In reality, the digital transformation of a business is a broader phenomenon than the digitization of a single product, service, or any activity of the company. This also relates to various business processes of the company. [6]. For this digital transformation, it is essential to have IT advancements that facilitate the flow and management of data.

Internet of Things

Az Internet of Things refers to a technology that enables the interconnection of various smart devices or machines over the Internet, creating a network. The essence of this is that these objects can collect and share data with each other through this network. [7] This technology can be applied in many areas of life, including healthcare, industry, or even smart homes and smart cities.

IoT devices can be extremely useful in logistics as well, providing numerous advantages to companies that employ them. It can enhance storage efficiency with the help of various smart shelves and autonomous vehicles, enabling the tracking of goods and more efficient arrangements in the warehouse. However, traceability is not only achieved within the warehouse but also in transportation, thanks to GPS–based devices or, for example, RFID (Radio–Frequency Identification) tags that allow precise location tracking.

Sensitive goods, such as various food items or medicines, often occur in storage or transportation, requiring continuous attention. IoT sensors can alert if environmental conditions are not suitable for sensitive goods, allowing for quick and immediate resolution of emerging issues.

Logistics companies also commonly use IoT devices for the maintenance of machinery and vehicles. These devices can continuously monitor the condition of machines and vehicles. Based on the data collected during monitoring, predictive maintenance is performed, enabling the prediction of potential faults.

With the help of IoT technology, security has also been elevated to the next level, thanks to small sensors placed in the warehouse. These devices monitor the entrances of warehouses and can send notifications about potential security incidents.

Big Data

The term Big Data lacks a formal definition, but it could best be summarized as a vast amount of information that cannot be understood in small quantities. [8]

Processing current datasets is increasingly challenging; traditional database management is no longer capable of handling the complexity of information at such a scale and pace. Big Data Analytics encompasses a complex technological environment, including all software, hardware tools, and models that facilitate the management of digitally detectable data. [9]

The analysis gathers data, which can be structured, partially structured, or unstructured, and prepares them for processing. After processing, the data are cleaned of invalid or incomplete fields, and formatting errors are corrected or deleted. The analysis is carried out using modern tools and techniques such as artificial intelligence, data mining, or machine learning. Thanks to this, patterns and relationships can be identified that human labor cannot deduce or perceive.

What can be particularly helpful is error analysis or supply chain optimization, whether in route planning or warehousing. It can optimize inventory turnover, facilitating storage and retrieval, and in route planning, it can search for and plan optimal routes based on available

traffic and route information. It can also assist in maintaining positive relationships with customers, helping us understand how to be chosen and how to improve the quality of our service. Market mapping is a complex and lengthy process, which Big Data Analytics simplifies, assisting in the search for new markets and the expansion of existing ones

Cloud Computing

Cloud computing provides high–performance servers and infrastructure that ensure the accessibility, storage, and processing of data over the Internet. [10] Among cloud–based services, Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS) systems can be distinguished. In the first case, infrastructure is provided for storage and computing capacity. PaaS provides an environment for various applications, and in the case of SaaS, the software itself is offered as a service. [11]

The main advantage of cloud–based services is the location– and time–independent access to data. However, a disadvantage is that access to the cloud is only possible through (private or public) networks. It is crucial, though, that clouds are adequately secured, as technology evolves alongside hacking techniques.

Security systems are capable of monitoring the state of the cloud, and detecting and mitigating attacks. The adoption of cloud computing also maintains the competitiveness of companies, as it can provide environments for, for example, Big Data analysis, which is now an element of many company strategies.

ChatGPT

"Artificial intelligence," refers to machines that can perform tasks entrusted to them that require human intelligence. The goal of artificial intelligence is to create machines and systems capable of thinking, learning, making decisions, and solving problems, much like the human brain operates. [12]

One such AI system is ChatGPT, which has become extremely popular as a chatbot in recent times.

The operating principle of GPT models, including ChatGPT, is based on machine learning and involves several steps:

1. data collection
2. preprocessing
3. learning
4. interpretation
5. refinement

In short, a large amount of textual data, such as books, articles, or social media posts (in logistics, this could be emails, inventory levels, arrival times, etc.), is collected. The input data is then tokenized, breaking the text into smaller characters and words. After cleaning and preparing, the data becomes more understandable and easier for the machine to process. The model learns from this input data. When a user poses a question, the machine breaks it down into input tokens and provides a meaningful response, thereby streamlining office work by eliminating constant data searches and filtering by employees.

The model is continually developed based on user feedback and responses to further enhance its capabilities.

CONCLUSIONS

The excessive application of digital technology in logistics can pose numerous risks. While digital technology offers many opportunities to increase efficiency and optimize processes, inadequate planning, system errors, or other issues raise some risks, such as cybersecurity.

The use of IoT devices emphasizes the critical role of data security. Therefore, it is essential to establish a proper security system to protect our data. As these devices are connected to the internet, they are exposed to significant risks, including cyber–attacks. If the devices or networks are inadequately protected, attackers can easily access data and potentially take control of the devices. However, preparation for such attacks is possible.

It is recommended to integrate security mechanisms into the devices, such as encryption or authentication mechanisms. Additionally, firewalls or access controls are worth implementing to prevent unauthorized access. Regular security updates for devices and software are crucial. Finally, it is advisable to choose reliable IoT devices and service providers who prioritize cybersecurity.

However, the application of digital systems increases the quantity and complexity of data, leading to additional data integrity issues. In cases of incorrect or poorly managed data, inaccuracies in information can cause serious problems in logistics decision–making.

Many studies suggest that excessive digitization makes logistics systems excessively dependent on technology. This means that if a system fails or shuts down, the entire logistics chain may be affected, making it challenging to transition to manual processes. This is an ongoing issue, as

even today's logistics systems struggle to function with manual control. Any failure or shutdown of an automated warehouse system, for example, can cause significant delays and issues in the supply chain.

Unfortunately, there is no optimal solution; technology must be used, and those who resist new system directions will fall behind. Thus, risk mitigation is the only viable path for logistics players, considering factors such as cybersecurity and the importance of human labor. Thorough planning and continuous monitoring can help minimize these risks.

In conclusion, cautiously applying modern technologies can improve current systems and aid in joining and remaining competitive within the industry.

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REMEDY OF SOILS CONTAMINATED WITH PETROLEUM HYDROCARBONS USING BIODEGRADABLE ABSORBENT

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Abstract: In this paper, we present a method of remediation of oil–polluted soils, using a biodegradable material, it is a material made of natural peat–type fibers. The rate of absorption of petroleum hydrocarbons by the peat is influenced by the size of the particles, the smaller they are, the higher the degree of absorption of petroleum products. We analyzed the absorption efficiency of petroleum hydrocarbons by the peat. By using peat for depollution, the soil is purified from petroleum products through sorption, soil fertility is improved, peat is rich in biogenic substances beneficial to the development of bacteria that reduce petroleum hydrocarbons.
Keywords: soil pollution, biodegradable absorbent, material, granulosity

INTRODUCTION

Greenhouse gas emissions from the environment are methane released from agriculture and natural gas handling and carbon dioxide, obtained from the burning of fossil fuels. Oil and hydrocarbon pollution, affects the environment and human health. Hydrocarbons are frequently used as a fuel source. Some uses of these compounds are derived from natural gas and petroleum. The latter are transformed, in turn, into propylene, ethylene or synthesis gas. Soil pollution with petroleum hydrocarbons results from anthropogenic sources resulting from industrial, agricultural and other activities (burning of fossil fuels for heating homes, incineration of waste, oil spills, burning of gasoline and diesel) and from natural sources (burning of waste, forest fires, volcanoes) (*Rocha, I. et al, 2019, Ambaye, T.G. et al., 2022, Rada, E.C. et al., 2019*).

Through pollution, soils change their physical and chemical properties, seed germination and crop growth are affected (*Evans, M. et al., 2016*). These polluted soils contain polyaromatic hydrocarbons, phenols, long–chain toxic hydrocarbons and must be remediated before they can be safely used.

Over time, methods have been sought to remediate the soil polluted with petroleum hydrocarbons, taking into account: the type of hydrocarbons, the characteristics of the location, the use of the depolluted land, the costs of depollution. Worldwide, researchers have turned their attention to finding the best methods for remediating soils polluted with petroleum hydrocarbons. Thus, treatment techniques were used for soil depollution: biological, physical, chemical, thermal and bioremediation, the use of biodegradable absorbents such as peat, which is rich in humic substances and has a high capacity to absorb pollutants from the soil, was tried (*De–Chang, Li et al., 2018, Olkova, A., 2022, Ghaly AE and Pyke, 2001*). By using peat for depollution, the soil is purified of petroleum products through sorption, soil fertility is improved, peat is rich in biogenic substances beneficial to the development of bacteria reducing petroleum hydrocarbons (*Gao Y.C. et al., 2014*).

The toxicity of hydrocarbons varies depending on: unsaturated compounds, the content of low–boiling compounds, acids and aromatic substances. The oil is more toxic the higher the concentration of these compounds. Once inside a plant, oil can migrate into the intercellular spaces and vascular system. Damage to cell membranes is achieved by the penetration of hydrocarbon molecules, which leads to leakage of cell contents, and oil can enter the cells.

In this work, the biodegradable absorbent peat is analyzed, which is rich in humic substances and has a high capacity to absorb pollutants from the soil (*Prodea, I.M., Sporea, N., 2018*).

CHARACTERIZATION OF THE SOIL – SUBSOIL – GROUNDWATER SYSTEM

The speed of movement of the liquid pollutant in the vertical or lateral direction is dependent on the characteristics of the pollutant (composition,

density, viscosity, polarity, etc.) and on the characteristics of the soil – subsoil – groundwater system (soil composition, soil structure, humidity) (*Popa, M, 2018*).

The characterization of the soil – subsoil – underground water system is carried out by establishing the thicknesses of the specific layers up to the first impermeable layer and by analyzing the characteristic parameters that influence the dispersion of pollutants (*Popa, M, 2018*).

Figure 1 shows the structure of the soil – subsoil – underground water system, the sizes of the layers varying between very large limits, depending on the geology and concrete conditions in the respective area (*Popa, M, 2018*).

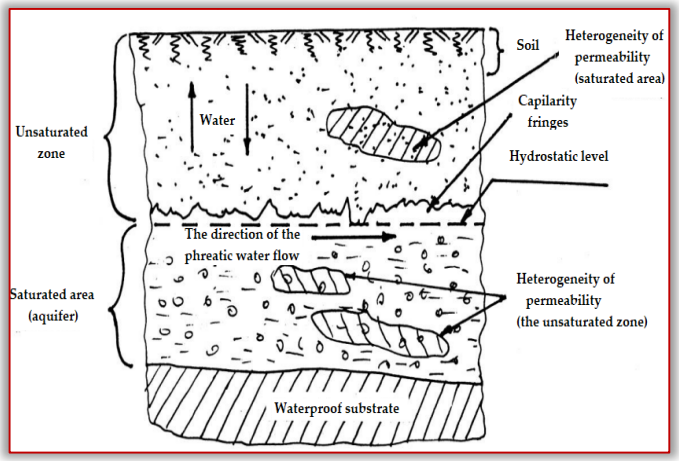

Figure 1 – The structure of the soil – subsoil – underground water system (Popa, M, 2018)

Figure 2 shows the specific areas that form over a relatively long period of time in the case of spilling a large amount of oil product on the soil surface. The liquid pollutant can reach the first water table and migrate with it, at a relatively high speed, to areas far from the place where the polluting incident occurred.

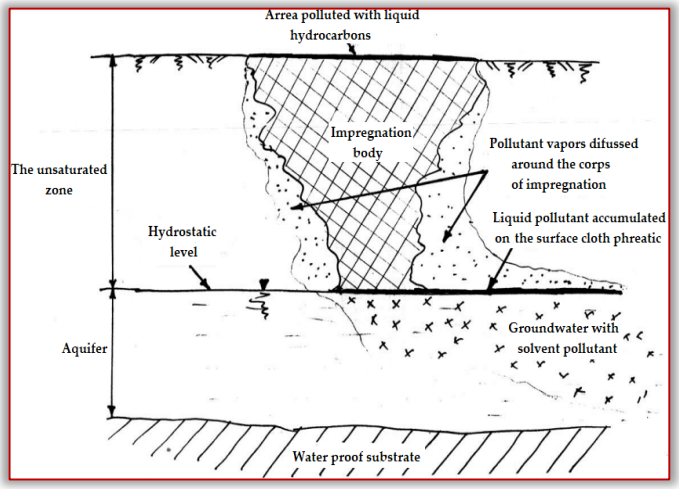

Figure 2 – Migration of a liquid petroleum pollutant in the soil–subsoil–groundwater system (*Popa, M, 2018*)

The toxicity of hydrocarbons varies depending on: unsaturated compounds, the content of low–boiling compounds, acids and aromatic substances. The oil is more toxic the higher the concentration of these compounds. Once inside a plant, oil can migrate into the intercellular spaces and vascular system.

Damage to cell membranes is achieved by the penetration of hydrocarbon molecules, which leads to leakage of cell contents, and oil can enter the cells. Hydrocarbons reduce the rate of transpiration by blocking stomata and intercellular spaces, reducing photosynthesis. Due to oil pollution, mitochondria are damaged, respiration rate increases. These negative effects occur depending on: plant species, environmental conditions and the amount of oil (*Odukoya, L. et al, 2019*). The classification of petroleum hydrocarbons is shown in figure 3. They are classified into heterocyclic and aromatic aliphatic hydrocarbons (*Balint, 2021; Bojan et al., 2021*).

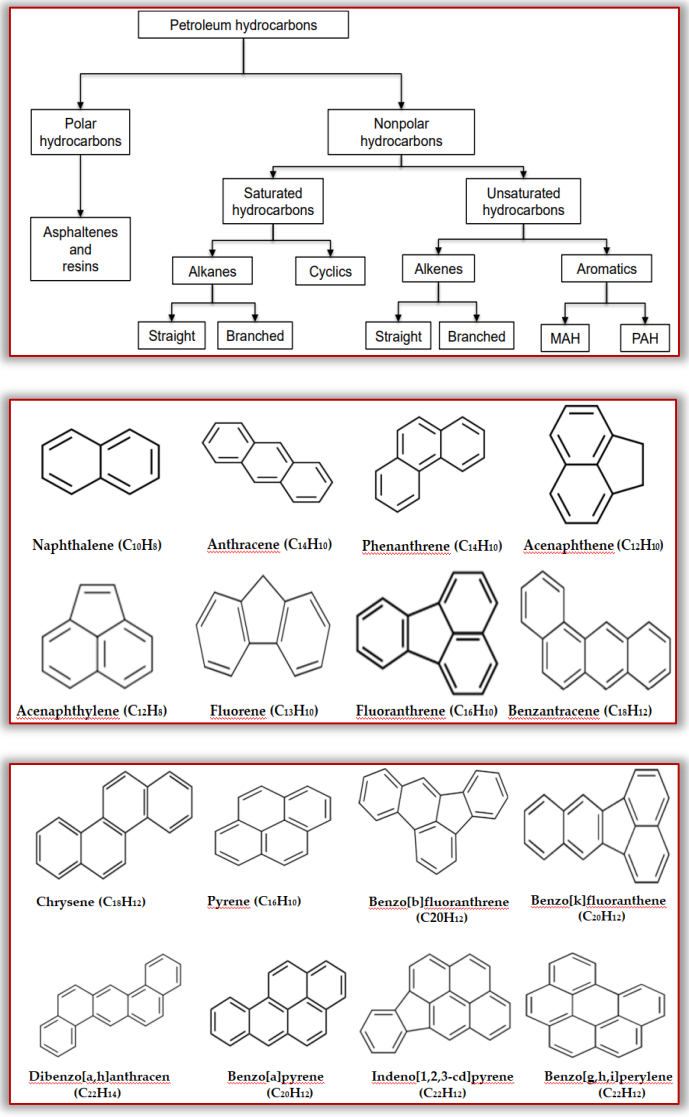

Figure 3 – Types of petroleum hydrocarbons *(Odukoya, L. et al, 2019)*
PAH –Polycyclic aromatic hydrocarbons, Monoaromatic hydrocarbons

SOURCES OF SOIL POLLUTION WITH PETROLEUM HYDROCARBONS

Soil pollution with oil is due to oil spills during the loading of tanks, during transport, accidental spills. The sources can be anthropogenic, from human activities (*Shahzadi, 2021*).

Annually, 1.7–8.8 million metric tons of petroleum hydrocarbons are spilled into the environment (*Shahzadi, 2021*).

Petroleum hydrocarbons are transported in the environment starting from production, transport, storage, then move into air, water, soil and terrestrial and aquatic ecosystems.

The sources of soil pollution with petroleum hydrocarbons are shown in figure 4.

Figure 4 – Sources of soil pollution with petroleum hydrocarbons *(Ambaye, T.G. et al, 2022)*

BIOREMEDIATION OF SOILS CONTAMINATED WITH PETROLEUM HYDROCARBONS

Peat (figure 5), obtained from the processing of peat moss, has the following characteristics presented in table 1.

Table 1. Physico–chemical characteristics of peat.

Peat	Values
physical condition	solid
pH	3.5–6
dry density	68.5 [g/dm^3]
auto–ignition temperature	200–260 [^{0}C]
humidity	8.5 [%]
specific weight	60–90 [g/l]
peat moss	85–87%
water and other organic elements	15 –13%

The natural biodegradable absorbent peat is applied to the polluted soil. This is a method of in situ treatment of oil–polluted soils. The humidity of the soil used in the experiment was 14% (g/g) and the average temperature of the soil was 14^{0}C. The rate of absorption of petroleum hydrocarbons by peat is influenced by the size of the particles, the smaller they are, the higher the degree of absorption of petroleum products.

Figure 5 – Biodegradable absorbent

Table 2 shows the sorption capacity of petroleum hydrocarbons by the peat depending on the granulation size. It is observed that the smaller the granulation, the higher the gasoline absorption capacity.

Table 2. Particle size of petroleum hydrocarbon sorbent (*Novoselova, L.Yu, Sirotkina, E. E. 2008*).

Particle size composition of the proposed sorbent	Particle size [mm]	Sorption capacity, for diesel fuel [g/g]
Plant residues	>3	4.10
Coarse fraction	2–3	5.52
Medium fraction	1–2	7.34
Small fraction	0.5–1	7.35
Coarse dust fraction	0.25–0.5	6.23
Fine dust fraction	≤0.25	6.04
Medium and small fractions (1 : 1.5)	–	7.50
Medium and small fractions (1 : 1)	–	7.71

The content of petroleum hydrocarbons in the treated soil (TS) and in the untreated soil (NS) for all 60 days of the experiment period is shown in figure 5. It can be seen that at the end of the experiment, in the soil treated with absorbent material based on peat, the hydrocarbons oil tankers were absorbed in a percentage of 95%.

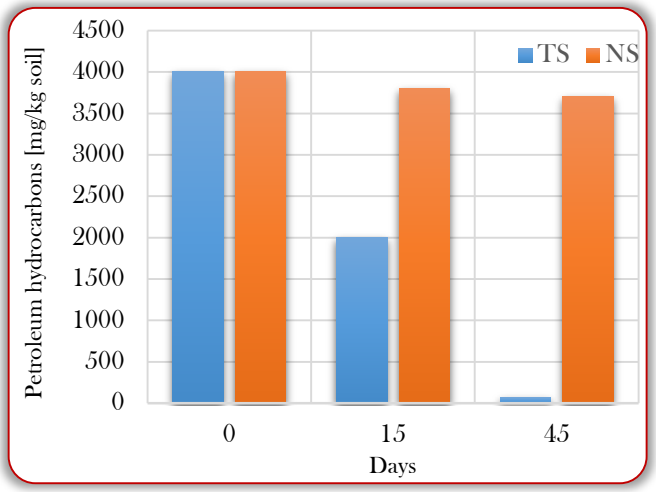

Figure 6 – Petroleum hydrocarbon content

The efficiency of removal of petroleum hydrocarbons is calculated with formula (1), (*Prodea and Sporea, 2018*).

$$\eta_i = \frac{PH_i - PH_j}{PH_i} x100 \quad [\%] \qquad (1)$$

where: j–day of the experiment; PHi the initial concentration of hydrocarbons; PHj the concentration of hydrocarbons from certain days of the experiment.

CONCLUSIONS

The topic addressed is part of the current concerns regarding research in the field of remediation of polluted soils. The need for research derives from the extent and degree of complexity of the problem of soil pollution, the impact of human activities on soil quality intensifying over the last decades due to population growth, extensive exploitation of natural resources, the development of industries and even agriculture.

In this paper, the role of biodegradable absorbent material for the recovery of gasoline–polluted soil was observed. By adding the biodegradable absorbent material to the polluted soil, the properties of the soils were improved. The absorption of petroleum hydrocarbons is 95%. This is a method of in situ remediation of soils polluted with petroleum hydrocarbons.

The effectiveness of soil remediation treatment depends on several factors: the concentration of pollutant applied, the type of contaminants, the amount of soil to be treated, and other factors.

The rate of absorption of petroleum hydrocarbons by the peat is influenced by the size of the particles, the smaller they are, the higher the degree of absorption of petroleum products.

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THE IMPACT OF SOIL PROPERTIES ON LEACHATE CHARACTERISTICS AND AVOCADO SEEDLINGS GROWTH

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Abstract: It was established that local soil texture was characterized as silt and handmade substrate as silt loam. It was established that the share of sand fraction in local soil is less than 2 times compared to the handmade substrate. Leachate pH and EC of local soil were a little bit higher than in handmade substrate. It was established that the leaves square of avocado plants growing in silt loam substrate is more than 15 % compared to silt local soil. Obviously, the best opportunities for infiltration of irrigated water are the leading factor in ensuring the development of the Avocado plant.
Keywords: soil, texture, leachate, leaf square, avocado

INTRODUCTION

Avocado cultivation amounted to 12,832 ha, and most of this area is located in SE Spain (Andalucía) with 10594 ha (83%), followed by the Canary Islands (13%) and Valencia (9%) provinces (*OPM–CAGPDS, 2022*). The Mediterranean climate is characterized by scarce and irregular rainfall. The average annual rainfall in some areas in SE Spain varies between 500 and 300 mm per year (*Gonzalez–Hidalgo et al., 2003*).

Andalusia avocado production represents 82% of the national total (*Rodríguez et al., 2009*). Due to the elevated prices of the avocado fruit, many farmers invest in planting avocados in hill slope areas on terrace orchards and establishing irrigation systems (*Durán et al., 2013*). Current avocado productionhas a significant impact on water access for local communities and generate water stress (*Sommaruga and May, 2021*). Thus, transfer from management practices that degrade soil quality to organic system is necessary since water quality deterioration is considerably lower than in conventional agriculture. It is necessary to redesign irrigation strategies in Mediterranean areas, focusing on the benefits of sustained–deficit irrigation, which can save water, encourage water use efficiency and enhance fruit quality (*Durán et al., 2021*).

Avocado is usually grown in arable lands having saline irrigation water (an EC greater than 0.75 dS/m (Crowley, 2008).The dramatic differences were in the amount of leaf damage among rootstocks after 23 months of irrigation with water having an EC of 1.5 $dS \cdot m^{-1}$ (*Celis et al., 2018*). Salinity had a significant influence on the growth pattern of the avocado seedlings, affects photosynthesis by stomatal limitations and led to salt accumulation in young leaves (*Lazof and Bernstein, 1997; Parida and Das, 2005; Munns and Tester, 2008*).

Different growth reductions and leaf necrosis were indicated among avocado cultivars under salt stress (*Mickelbart and Arpaia, 2002*). Salinity affects photosynthesis by stomatal limitations, led to salt accumulation in young leaves and considerable decrease in the weights of leaves, stems, tillers and roots of susceptible (*Parida and Das, 2005; Munns and Tester, 2008; Berkessa, 2020*). Salinity problems are more difficult to solve in clay soils (*Crowley, 2008*). High clay soils that have poor drainage are particularly problematic in that salts are not easily leached.

The main objective of our case study was to estimate the impact of soil properties on leachate characteristics and avocado seedlings growth.

MATERIALS AND METHODS

The subtropical climatic conditions required for the development of the avocado tree in Malaga province. The climate of this region is characterized by temperate average temperatures (~20 C throughout the year) with high environmental humidity. The region is a narrow strip about 12 km wide parallel to the Mediterranean coast that has a special

microclimate due to the arrangement of the intertropical valleys, which have a north–south orientation and are protected against northerly winds by the Penibetic mountain range, which runs towards the edge of the coast from east to west.

The achievement of the exposed objectives were carried out in the facilities of the "La Mayora Experimental Field site", of the Higher Council for Scientific Research (CSIC), which is therefore representative of the agricultural holdings of the environment, and which has the same problem. The pot experiment with avocado was monitored last three months. The soil texture and particles size were determined with "Mastersizer" (Figure1).

Figure 1 – Soil texture measurement

The preliminary made avocado leaf square calibration method was developed to avoid necessity to cut leaves in pot experiment. A leaf print was obtained using Xerox. Then the contour of the print was outlined. Having received in one way or another imprint of the sheet, determined its area. The area of the sheet under study was found by the formula:

$$S_x = \frac{a \cdot c}{b}, [cm^2] \quad (1)$$

where: a – the mass of the leaf contour, mg;
b – the mass of a square of paper, mg;
c – the area of a square of paper, cm².

Next step required from us just to measure two leaf size indexes – length (L) and width (W) to know ratio coefficient (RC) between S_x , L and W:

$$RC = \frac{S_x}{L \cdot W} \quad (2)$$

Measured date on length and width of avocado leaves in two trials (local soil) and hand prepared substrate (sandy loam) were calculated using formula:

$$S_i = L \cdot W \cdot RC, \quad (3)$$

where S_i – calculated leaf square, [cm²].

RESULTS

The particle size assessment allowed establishing that local soil texture characterised as silt, and handmade substrate as silt loam. It is known that optimal sand content is main pre–requisite to provide infiltration process during vegetation period.

The data on sand content in local soil (Silt) and handmade substrate (Silt Loam) are shown in the figure 2. It was established that the share of sand fraction in in local soil is less than 2 times comparative to handmade substrate.

Figure 2 – Sand fraction content in local soil and handmade substrate, %

The data on underground water ions content are shown in the Table 1.

Table 1. Ions content of the underground water, mg/L

Ion	F	Cl	NO_2	Br	NO_3	SO_4	Na	K	Mg	Ca
Content [mg/L]	0.32	66.64	0.06	0.38	41.10	116.71	60.89	4.04	56.89	55.71

There is different assessment on suitability of water for Irrigation including irrigation coefficient known as SAR (Sodium Adsorption Ratio):

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}} = 8.0$$

In our case SAR of the groundwater is 8 and may be estimated as permissible (Table 2).

Table 2. Suitability of Water for Irrigation

Quality	SAR	pH
Exelent	3	6.5
Good	3–5	6.5–6.8
Permissible	5–10	6.8–7.0
Doubtful	10–15	7.0–8.0
Unsuitable	>15	>8.0

It was known that avocado develop severe leaf burn if the SAR of the irrigation water is more or about 6–10 (*Branson and Gustafson, 1971*). In our case SAR of the local ground water is 8. Avocado seedlings were irrigated with ground water last three months. It was connected with our first task to see impact of tested soil on leachate pH, EC and chemical content. The two

portions of data obtained are shown to compare local soil and handmade soil substrate in pH and EC (Figure 3 and 4).

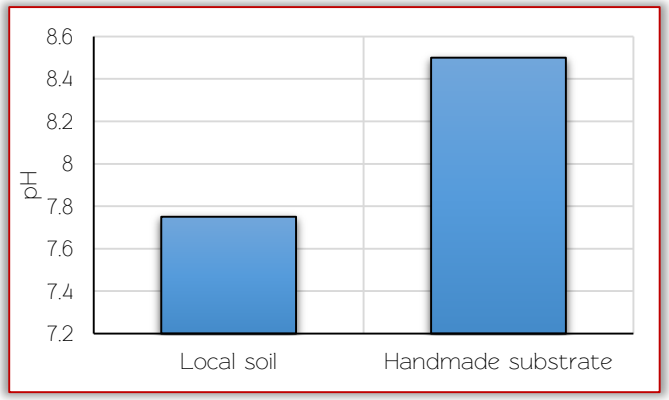

Figure 3 – Leachate pH

Figure 4 – Leachate conductivity, ds/m

American scientists from California Davice University established that maximum yields of 'Hass' avocado on Mexican seedling rootstock are not achievable when the average annual salinity of irrigation water, including rainfall, is greater than '0.6 dSm^{-1}(*Oster et al., 2007*). An ECe of 2 dS/m could be a salinity level that limits water uptake (*Bernstein and Francois, 1973*) by Mexican seedling rootstocks. In our case the leachate pH and conductivity was between 7.8–8.5 and 1.85 to 2.05 ds/m correspondingly.

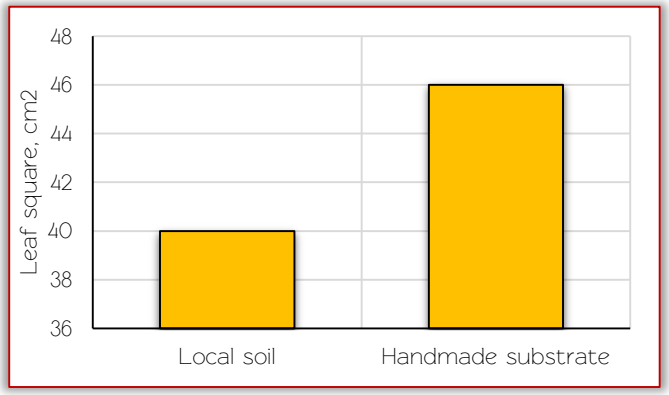

Figure 5 – Leaf square of avocado growing in silt local soil and silt loam substrate, cm^2

The meaning of ratio coefficient of avocado leaves, obtained after calibration procedure was 0.61.The data obtained for two trials (local soil and silt loam substrate) are shown in the figure 5.

It was established that leaves square of avocado plants growing in silt loam substrate is more than 15 % comparative to silt local soil. This difference can be explained more high level of irrigated water through handmade substrate with infiltration comparative with local soil.

CONCLUSIONS

It was established that local soil texture characterised as silt, and handmade substrate as silt loam. It is known that optimal sand fraction content is main pre–requisite to provide infiltration process during vegetation period. It was established that the share of sand fraction in in local soil is less than 2 times comparative to handmade substrate.

Sodium adsorption ratio of irrigated ground water was estimated as 8 or permissible. Leachate pH and EC of local soil were a little bit more than in handmade substrate.

It was established that leaves square of avocado plants growing in silt loam substrate is more than 15 % comparative to silt local soil. This difference can be explained more high level of irrigated water through handmade substrate with infiltration comparative with local soil.

Obviously, the best opportunities for infiltration of irrigated water are the leading factor in ensuring the development of the Avocado plant.

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RESEARCH ON THE ACHIEVEMENT OF A FUNCTIONAL INGREDIENT FROM CAULIFLOWER LEAVES BY LYOPHILIZATION

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Abstract: The European Commission has established food waste as one of the priority areas of the Action Plan on the European Strategy for the Circular Economy. Of all the biomass generated by cauliflower and broccoli crops, only 30% is used for food (the inflorescence); the rest of the parts, including leaves, stems, are considered as by–products (waste) which are mainly used for composting or incorporated into the soil. This paper presents the results of the research undertaken to obtain a functional ingredient (powder) by lyophilization of cauliflower leaves, resulting from the culture of this vegetable species. The functional ingredient was analyzed from a sensory, biochemical and microbiological point of view. This functional ingredient comes in the form of a green powder with a characteristic taste and smell. The biochemical analysis revealed that the powder obtained from the processing of cauliflower leaves is notable for its content in glucosinolates, total polyphenols, vitamin C, α–tocopherol, total carotenoids, β–Carotene, lutein, chlorophyll a, chlorophyll b. Due to the high content in bioactive compounds, the functional ingredient obtained from cauliflower leaves, has antioxidant capacity (21.94 µmol TE/g; 24.87 µmol TE/g).
Keywords: cauliflower, leaves, functional ingredient, lyophilization, bioactive compounds

INTRODUCTION

The consumption of green leafy vegetables represents only 37% of the recommended daily dose. Agricultural waste not only impede food security but also pollutes the environment (*Gebrechristos & Chen, 2018*).

The vegetable processing industry produces over one million tons of vegetable by–products every year, which are waste, but which constitute a potential source of bioactive ingredients (*Galali et al., 2020; Rafiuddin et al., 2019, 2021*). Studies undertaken internationally have shown that there is a huge potential for the use of by–products from plant sources for the development of food products (*Amoah et al., 2023; San José et al., 2018; Tamasi et al., 2019*). Cauliflower by–products have a high potential for valorization due to their complex biochemical composition. It is worth noting that cauliflower waste (leaves, stems) represents about 60% of the total weight of this vegetable (*Ribeiro et al., 2015*).

The European Commission has established food waste as one of the priority areas of the Action Plan on the European Strategy for the Circular Economy (*European Commission, Directorate–General for Research and Innovation, 2018*). This Plan includes a "zero waste" strategy (targeting agro–food waste) to reduce environmental pollution. This strategy is based on the superior recovery of food waste, through:

- obtaining functional ingredients with nutritional value and antioxidant potential, which can be used in the fortification of food products;
- extraction and concentration of bioactive compounds from food waste with a complex biochemical composition and their use in innovative and economically profitable applications in the food, cosmetic and pharmaceutical industries (*Saini et al., 2019; Jiménez–Moreno et al., 2019*).

International studies have shown that cauliflower by–products are an exceptional source of protein, vitamins, minerals, ascorbic acid, carotenoids, antioxidants and dietary fiber (*Montone et al., 2018; Munir et al., 2018; Stojceska et al., 2008*).

Cauliflower leaves have bioactive peptides found within native proteins that require to be released by enzymatic hydrolysis and bacterial fermentation during digestion. These bioactive peptides can improve the viability of human vascular endothelial cells by triggering the inhibition of intracellular xanthine oxidase activity and modulation of superoxide dismutase. Thus, cauliflower by–products can be additional sources of protein (*Caliceti et al., 2019*).

Cauliflower leaves which are a rich source of dietary fiber, crude protein, calcium, iron, carotene, lysine, tryptophan and natural antioxidants including phenols, and therefore can be used in different value added products (*Revathi et al., 2019*). These authors used the powder obtained from the dehydration of

cauliflower leaves at a temperature of 60–70°C, for the fortification of cookies (fortification levels of 5% and 10%). The sensory evaluation (appearance, taste, texture and aroma) of the fortified cookies, on a 9–point hedonic evaluation scale, revealed that the optimal level of fortification is 5%.

Furthermore, cauliflower and its by–products contain glucosinolates in very high concentrations up to 75,000 µg/g (*Sanlier & Guler, 2018*).

This paper presents the results of the research undertaken to obtain a functional ingredient (powder) by lyophilization of cauliflower leaves. The functional ingredient was analyzed from a sensory, biochemical and microbiological point of view.

MATERIALS AND METHODS

Waste (leaves) resulting from the conventional cauliflower culture, from farmers in Ialomița county, were used in our experiments. Pretreated cauliflower leaves (sorting, washing, boiling in water at 98–100°C for 2–3 minutes, cutting) were subjected to lyophilization process in a freeze dryer (Heto Power Dry PL 3000, from Thermo Electron Corporation) at – 55°C to a moisture which allows their milling and conversion into flours and, in the same time, gives their stability in terms of quality.

Figure 1 – Pretreated and freeze–dried cauliflower leaves

Milling of dried semi–finished products was performed by using Retsch mill (Knife Mill GRINDOMIX GM 200). Functional ingredient (powder) obtained from cauliflower leaves was packed in hermetically sealed glass containers, protected with aluminum foil and kept in dry and cool spaces (at a maximum temperature of 20°C), until the sensory, biochemical and microbiological analyzes were performed.

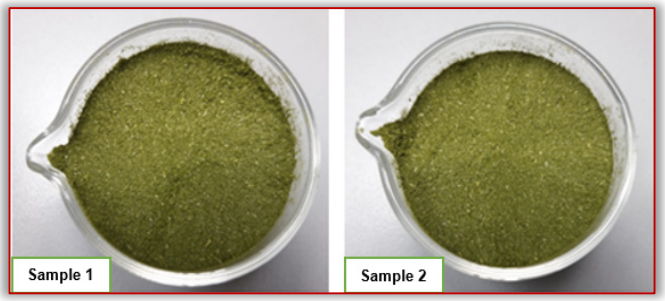

Figure 2 – "Functional ingredient from cauliflower leaves (powder)"

For the qualitative characterisation of the Functional ingredient from cauliflower leaves (powder) were used standardized methods and developed and validated methods in IBA Bucharest.

Measurement of the color parameters of samples was performed at room temperature, using a CM–5 colorimeter (*Konica Minolta, Japan*), equipped with SpectraMagic NX software, to register CIELab parameters (L*, a*, b*). The moisture content was determined according to the AACC 44–15A method. Protein content was determined by the Kjeldahl method with a conversion factor of nitrogen to protein of 6.25 (AOAC Method 979.09, 2005).

Fat content was determined according to AOAC Method 963.15, and ash content according to AOAC Method 923.03 (AOAC, 2005). Total dietary fibre (TDF) was determined by enzymatic method using the assay kits: KTDFR ''Total dietary fibre'' (AOAC Method 991.43).

Determination of iron, copper, manganese and zinc was performed by Inductively Coupled Plasma Mass Spectrometry (ICP–MS, model NexION300Q, Perkin Elmer) after dry digestion of the samples. The determination of sodium, potassium, calcium and magnesium was carried out by High–Resolution Continuum

Source Atomic Absorption Spectrometry (Analytik Jena, model contrAA 700 – High–Resolution Continuum Source Atomic Absorption Spectrometer), flame technique, after dry digestion of the samples.

Determination of the vitamin C was performed by high performance liquid chromatography coupled with mass spectrometry (*Catană et al., 2017*). Determination of vitamin E (a–tocopherol) content was performed by high–performance liquid chromatography (HPLC–DAD) (*Popović et al., 2015*). Determination of β–carotene and all–trans lutein content was performed by high–performance liquid chromatography (HPLC–DAD) (*Catană et al., 2020*). Total phenolic

content was determined by Folin–Ciocalteu procedure, and antioxidant capacity by DPPH method (Horszwald and Andlauer, 2011 with some modifications (concerning extraction media, time and mode of extraction, extract volumes of the used sample and reagents, using UV–VIS Jasco V 550 spectrophotometer). Determination of glycosinolate content was carried out using a rapid spectrophotometric method (*Mawlong et. al., 2017*). Determination of total carotenoids and chlorophyll a and b was carried out spectrophotometrically (*Chinnadurai et al., 2017*).

The water activity (Aw) was determined by the method ISO 21807:2004. Yeasts and molds were determined by the method SR ISO 21527–1:2009 and SR ISO 21527–2:2009. *Enterobacteriaceae* were determined according to the SR EN ISO 21528–2:2017 method and *Escherichia coli* by SR ISO 16649–2:2007 method. *Salmonella* was determined by the method SR EN ISO 6579–1:2017.

RESULTS

Following the sensory analysis, it was found that the functional ingredient from cauliflower leaves is in the form of a powder with a characteristic taste and smell and dark green colour (Figure 2). Following the instrumental color value, it was found that these powders recorded negative values of the color parameter a* and positive values of the luminance L* and the color parameter b* (Figure 3).

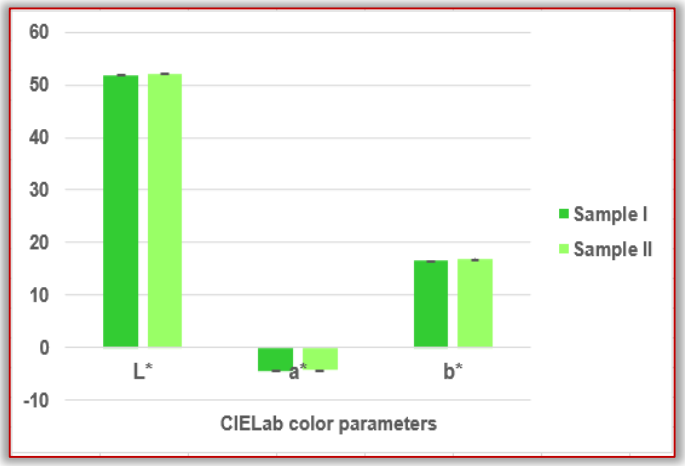

Figure 3 – Colour parameters of the "Functional ingredient from cauliflower leaves (powder)"

Physico–chemical analysis revealed that the functional ingredient of cauliflower leaves (powder) stands out for its content in protein, ash, total sugar and total fiber (Table 1). It is worth noting that Sample 2 recorded higher values of the determined physico–chemical indicators compared to Sample 1.

Table 1. The physico–chemical indicators of the"Functional ingredient from cauliflower leaves (powder)"

Physico–chemical indicators	"Functional ingredient from cauliflower leaves (powder)"	
	Sample 1	Sample 2
Moisture (%)	5.23±0.13	5.11±0.13
Ash (%)	10.64±0.16	10.95±0.16
Protein (%)	29.40±0.44	29.86±0.45
Fat (%)	4.38±0.06	4.70±0.06
Carbohydrates (%)	50.35±0.33	49.38±0.32
Total sugar (%)	18.30±0.12	19.16±0.12
Total fibre (%)	31.20±0.58	29.83±0.55
Energy value (kcal/100g)	296	300
Energy value (kJ/100g)	1237	1253

The "Functional ingredient from cauliflower leaves (powder)" has a higher ash, protein, fat content compared to that reported by Tukassar et al. (2023) in the case of cauliflower by–products powder (Protein = 22.80%; Ash = 5.81%; Fat = 2.95%).

The "Functional ingredient from cauliflower leaves (powder)" stands out for its content in mineral elements (Figure 4 and 5). Among the determined mineral elements, in the case of the "Functional ingredient from cauliflower leaves (powder)", potassium it recorded the highest content (Figure 4). Potassium is the most abundant cation in the human body, approximately 2% being located in the extracellular fluid (3.5–5.0 mEq/L) and 98% being in the intracellular area (140 mEq/L) (*Kovesdy et al., 2017; Kovesdy et al., 2017*). Potassium plays a crucial role in normal cell membrane electrophysiology in neurons, muscle, and cardiac cells (*Kovesdy et al., 2017*).

At the same time, according to our results, the "Functional ingredient from cauliflower leaves (powder)", can be considered an important source of calcium and magnesium. Calcium and magnesium are two mineral elements with an important role in the human body. Calcium and magnesium affect muscle mass and function and are important for optimal vitamin D status (*Hibler et al. (2020)*. Insufficient dietary intake of nutrients such as calcium and magnesium can be associated with increased risk of cancer, cardiovascular diseases, metabolic diseases and mortality (*Schwingshack et al, 2015; Asemi et al., 2015*).

The content in Cu, Zn and Mn of the "Functional ingredient from cauliflower leaves (powder)", recorded lower values, compared to other determined mineral elements, being in the range of 1.42–6.20 mg/100g.

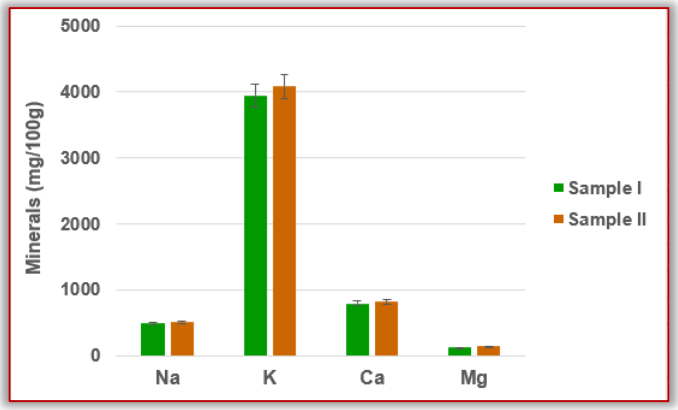

Figure 4 – Mineral content (Na, K, Ca, and Mg) of the "Functional ingredient from cauliflower leaves (powder)"

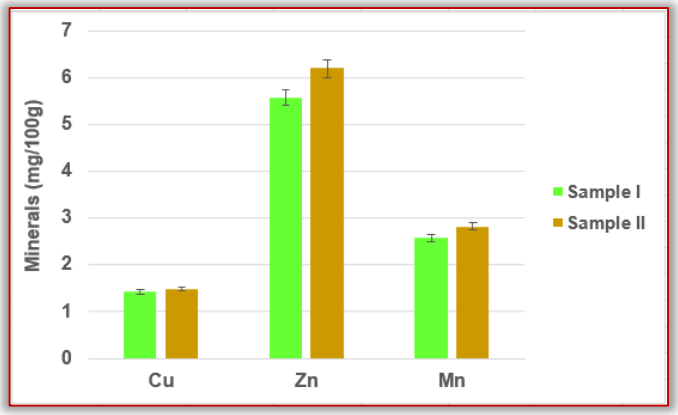

Figure 5 – Mineral content (Cu, Zn and Mn) of the "Functional ingredient from cauliflower leaves (powder)"

The "Functional ingredient from cauliflower leaves (powder)" stands out for its Fe content: Sample 1 = 41.65 mg/100g; Sample 2 = 48.52 mg/100g. Iron is an important bioelement and an essential dietary mineral for most life forms. In humans, iron is present in the body in various tissues and cells and plays an essential role in oxygen transport. Iron also plays a role in cell signaling, gene expression, and regulation of cell growth and differentiation.

Normally, total body iron remains within a relatively narrow range of normal values, about 5 g in adults, with about 65%–70% present in red blood cells as hemoglobin. Iron homeostasis is highly regulated through tightly controlled iron absorption. Iron deficiency is the most common micronutrient deficiency worldwide, accounting for about one–half of all cases with nutrient deficiency, and has a high incidence in developing countries driven by poor nutrition and parasitic infections (*Serai et al., 2020*).

The "Functional ingredient from cauliflower leaves (powder)" has the content in Mg, Fe, Zn and Cu, higher compared to that reported by Tukassar et al. (2023) in the case of cauliflower by–products powder (Mg = 36.3 mg/100g; Fe = 20.03 mg/100g; Zn = 1.46 mg/100g; Cu = 0.83 mg/100g).

It is worth noting that The "Functional ingredient from cauliflower leaves (powder)" is an important source of bioactive compounds: total polyphenols, glucosinolates, vitamin C, β–Carotene, lutein, chlorophyll a, chlorophyll b (Table 2).

Table 2. Bioactive compounds content of the"Functional ingredient from cauliflower leaves (powder)"

Bioactive compounds	"Functional ingredient from cauliflower leaves (powder)"	
	Sample 1	Sample 2
Total polyphenols (mg GAE/g d.m.)	8.97±0.22	9.95±0.25
Glucosinolates (mmol/g d.m.)	338.72±8.13	383.22±9.20
Vitamin C (mg/100g)	164.48±4.93	195.76±5.87
α–Tocopherol (mg/100g d.m.)	4.36±0.12	5.11±0.14
β– Carotene (mg/100g)	47.73±1.10	53.54±1.23
Lutein (mg/100g)	17.82±0.41	21.18±0.49
Chlorophyll a (mg/g)	1.98±0.02	2.19±0.02
Chlorophyll b (mg/g)	3.68±0.04	3.82±0.04

The "Functional ingredient from cauliflower leaves (powder)" obtained by lyophilization at –55°C has a higher content of bioactive compounds, compared to that obtained by dehydration with hot air, at a temperature of 50°C, as follows (Catană et al, 2023):

- 2.15 times, respectively, 2.44 times higher, in the case of vitamin C
- 1.88 times, respectively, 2.01 times higher, in the case of vitamin E
- 1.21 times, respectively, 1.26 times higher in the case of β–carotene
- 1.53 times, respectively, 1.60 times higher in the case of lutein
- 1.56 times, respectively, 1.68 times higher in the case of total polyphenols
- 1.41 times, respectively, 1.52 times higher in the case of glucosinolates.

At the same time, the total polyphenol content of this functional ingredient is 1.67–1.85 times higher, compared to that reported by Tukassar et al. (2023) in the case of cauliflower by–products powder (537.40 mg GAE/100g)

Due to the high content of antioxidants (β–carotene, vitamin C, vitamin E, total polyphenols, etc.) the "Functional ingredient from cauliflower leaves (powder)", shows antioxidant capacity: Sample 1 = 21.94 µmol TE/g; Sample 2 = 24.87 µmol TE/g. This functional ingredient obtained by lyophilization has an antioxidant capacity of 1,64–1,74 times higher compared to that of the ingredient obtained by dehydration with hot air, at 50°C (*Catană et al, 2023*).

Following the microbiological analysis, it was found that the "Functional ingredient from cauliflower leaves (powder)" falls within the provisions of the legislation in force and presents low water activity values (Table 3).

Table 3. Microbiological analysis of the"Functional ingredient from cauliflower leaves (powder)"

Microbiological indicators	"Functional ingredient from cauliflower leaves (powder)"	
	Sample 1	Sample 2
Yeast and mold (CFU/g)	< 10	< 10
Enterobacteriaceae (CFU/g)	< 10	< 10
Escherichia coli (CFU/g)	< 10	< 10
Salmonella (in 25 g)	Absent	Absent
Water activity	0.157	0.146

CONCLUSIONS

The "Functional ingredient from cauliflower leaves (powder)" obtained by lyophilization has high nutritional value and antioxidant potential. Thus, this functional ingredient stands out for its protein content, mineral elements (Na, K, Ca, Mg, Zn and Fe) and bioactive compounds (total polyphenols, glucosinolates, vitamin C, α–Tocopherol, β–Carotene, lutein, chlorophyll a, chlorophyll b).

The "Functional ingredient from cauliflower leaves (powder)" is a source of protein (min. 29%), total fiber (min. 28%), K (3500 mg/100g), Fe (min. 41 mg/100g), Ca (min. 750 mg/100g), Mg (min. 110 mg/100g). At the same time, this functional ingredient stands out for its total content of polyphenols (min. 8.5 mg GAE/g d.m.), glucosinolates (min. 300 mmol/g d.m.), vitamin C (min. 150 mg/100g), α–Tocopherol (min 4 mg/100g), β–Carotene (min. 40 mg/100g), lutein (min. 16.5 mg/100g), chlorophyll a (min. 1.4 mg/100g) and chlorophyll b (min. 3 mg/g) .

Due to the high antioxidant content, the "Functional ingredient from cauliflower leaves (powder)" has antioxidant capacity (min. 21.2 μmol TE/g).

Due to nutritional qualities and antioxidant capacity, the "Functional ingredient from cauliflower leaves (powder)" can be used for fortification of conventional and gluten–free bakery and pastry products.

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WEIGHT OPTIMIZATION OF A POST-TENSIONED CONCRETE BEAM

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Abstract: This research focuses on the weight optimization of a post-tensioned concrete section under the design guidelines of Eurocode 2. Research shows that optimizing concrete weight can lead to lighter members, smaller sections, and lower costs while maintaining safety and failure requirements. Microsoft Excel was used to develop and optimize the mathematically derived model representing the weight of the post tensioned beam and the constraints related to it. The minimum weight is assumed to coincide with the minimum section dimensions; hence, the design variables consisted of the dimensions of the beam's cross-section. The weight optimization process was demonstrated by comparing the initial and final values of both weights with respect to the beam span and live load on the structure. A weight reduction of 65.06% was observed at a span of 5 m, which then declined to a measly 2.3% when the span increased to 10 m. A similar result also occurred with respect to the applied live load; here a weight reduction of 57.21% was observed when a load of 3 kN/m was placed on the beam; this also reduced to 2.34% when the live load was increased to 8 kN/m.

Keywords: weight optimization, post-tensioned concrete section, Eurocode 2, optimization, serviceability constraints

INTRODUCTION

The main purpose of the design of prestressed concrete is to limit tensile stresses, and hence cracking due to bending moments, in the concrete under working conditions. The design of the prestressed beam in this research is therefore based initially on the requirements of the serviceability limit state.

Prestressing in itself is the process of inducing compressive stress zone of a structural element, which may become tension under external loads. The introduction of compressive stress in the structural element helps to neutralize the tensile stress that may occur so that there is no resultant tension. This means that cracking in the structural part has been fully eradicated under working load, and all of the concrete can be assumed to be effective in carrying load. As a result, lighter sections can carry a given bending moment over much longer spans than reinforced concrete.

Given that the prestressed member is lighter than an identical reinforced concrete member of the same function under the same load, weight optimization is often not considered in the design of prestressed members. In addition, not only is the concrete in the member fully utilised, but also the need for conventional steel reinforcement with bars is unnecessary. The compressive force is usually provided by tensioned steel wires or strands which are anchored against the concrete and, since the stress in this steel is not an important factor in the behaviour of the beam but merely a means of applying the appropriate force, full advantage may be taken of very high strength steels. Hence, the weight of the steel tendons, compared to the concrete is negligible.

Despite the prevalence of Eurocode 2 and its detailed provisions for post-tensioned concrete design, there are still challenges associated with optimizing the weight of post-tensioned concrete beams while maintaining compliance with safety and structural integrity requirements. The problem is multifaceted, involving the need to reduce material usage to promote sustainability and cost-effectiveness, while concurrently ensuring that the structural performance remains reliable.

This research aims to address the aforementioned problem by focusing on the weight optimization of post-tensioned concrete beams while adhering to the guidelines and constraints set forth by Eurocode 2. The optimization process will involve a systematic exploration of design variables, such as concrete strength, beam geometry, and eccentricity of prestressing force with the goal of achieving the most efficient and permissible structural configuration. Advanced computational methods and optimization algorithms will be employed to search for optimal solutions within the defined design space.

The literature surrounding the optimization of post-tensioned concrete structures is rich and diverse. Previous research has predominantly centered on various aspects of post-tensioned concrete design, ranging from detailing and construction techniques to material properties and structural behavior. However, limited research has explicitly focused on the weight optimization of such structures within the

Eurocode 2 framework. Reinforced Concrete Design to Eurocode 2 (Mosley, *et al*., 2012) was studied to investigate the design of post-tensioned concrete beam to Eurocode 2 specifications. It also illustrates the assumptions, design parameters and constraints to be made by the designer when developing an optimization model for the structure within the Eurocode 2 framework.

Chapra and Canale (2015) was thoroughly studied as it discusses the various optimization processes and how they are to be used. It also presented a list of optimization algorithms consisting of: the simplex method, generalized reduced gradient (GRG) search method, genetic algorithms, simulated annealing and Tabu search. In addition, it showed how for the various optimization problems, different algorithms could be applied through the use of Microsoft Excel software by the means of its SOLVER tool which applies either the simplex method, evolutionary algorithm (genetic algorithm) or generalized reduced gradient (GRG) methods.

Oded and Emad (2018), focuses on the optimization of prestressed concrete beams by optimizing the distribution of material in a given design domain. Similar to the aim of this research, it focuses on adjusting the geometry of the beam to achieve the research work's stated targets.

Dissanayake and Jothy (2007), is another research work with similar objectives as this one. This research used Microsoft Excel and SAP2000 structural analysis to organize, manage and direct for solving and optimize a pre-stressed concrete beam section. The cost of manufacture was the objective function, and its optimization was achieved by minimizing the cross-sectional area of both the concrete, steel tendons and compression reinforcement.

Krauser (2009) examines a parametric study of a post-tensioned flat plate floor system. To construct the parametric analysis of a hotel/condominium grid plan, the load balanced by post-tensioning, slab depth, and concrete strength were modified. To carry out the parametric study, research on the development of post-tensioning, methods of analysis for two-way slab design, and posttensioning techniques of analysis were carried out. The design was done by hand using a series of Excel spreadsheets.

Samartin and Utrilla (1990) provide a review of the current strategies for optimizing prestressed concrete bridge decks. The sizes of prestressing cables with a given fixed geometry are determined using linear optimization. This simple procedure of linear optimization is also used to obtain the 'best' cable profile, by combining a series of feasible cable profiles.

Shengping and Tiong (2004) evaluated the cost effectiveness of post-tensioned concrete structural systems, taking into account various grid systems and loads to determine the best cost efficient solution for a building. The work investigated the costs of materials, labor, transportation, and necessary equipment. The paper focuses on construction in Singapore and provides an example of how to do a cost analysis. The variables of material cost and labor cost will be used in the cost analysis for this project.

The scope of this research encompasses a comprehensive investigation into the weight optimization of post-tensioned concrete beams, with a primary focus on Eurocode 2 compliance. The study will involve weight optimization on a selected beam with defined parameters, a demonstration of the weight optimization procedure with respect to various applied load values, and a performance of the weight optimization procedure with respect to various span lengths of the beam.. The justification for this work lies in the increasing demand for sustainable construction practices, where reducing material usage and enhancing structural efficiency are paramount.

Given that the weight of steel in the post-tensioned beam is negligible (at serviceability limit state), the weight of the concrete can be optimized, leading to lighter members, smaller sections and all at a cheaper cost while still fulfilling safety and failure requirements. By optimizing the weight of post-tensioned concrete beams, this research contributes to the broader objectives of sustainability, safety, and cost-effectiveness in civil engineering.

Since the weight optimization is achieved by minimizing the cross-section properties, the model could also serve as a means of topological (shape) optimization. It could also be further developed to handle larger and less-idealized post-tensioned members like bridge-girders, with the consideration of the member at ultimate limit state or compression reinforcements.

A main goal of the research was to have a thorough grasp of Eurocode 2 and its requirements for post-tensioned concrete

design. This was then followed by an investigation into the important design variables and limitations influencing the weight optimization of post-tensioned concrete beams. An accurate depiction of the behavior of post-tensioned concrete beams could be achieved using created computational models, as well as recommendations for practical implementation and future study in the field of post-tensioned concrete optimization. In pursuit of these goals, our research intends to give significant insights and practical solutions to the optimization of post-tensioned concrete beams, in line with the construction industry's increasing needs.

MATERIALS AND METHODS

Materials

Eurocode 2 (2004) was used to develop a mathematical representation of a concrete structure. An Excel spreadsheet was used to set up the model and the optimization process was executed using Excel's Solver Tool.

Development of the Objective Function

Consider the transverse section of a post-tensioned concrete beam as shown in Figure 1.

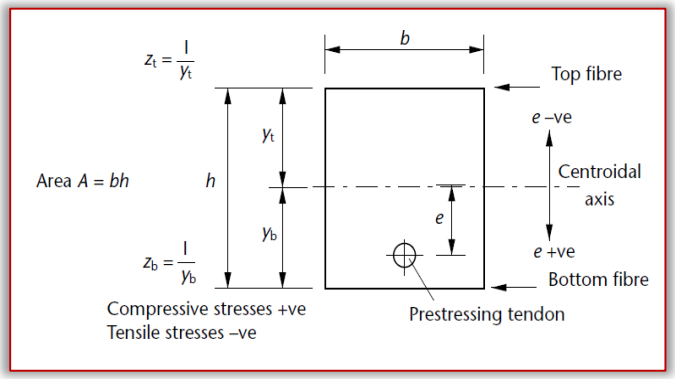

Figure 1: Cross-section of a post-tensioned concrete beam.

The weight of the post-tensioned beam was taken as a function of the density of concrete, cross-sectional area of the beam and its span.

$$\text{Weight, } W = \rho \times b \times h \times L \quad (1)$$

where:

ρ, is the density of the concrete grade.
b, is the width of the beam.
h, is the height of the beam.
L, is the span across the beam.

Required Inputs

These are the terms and parameters needed to calculate and derive the objective function, constraints and other relevant parameters.

The geometric properties of the beam considered include:

— The width of the beam (b).
— The height of the beam (h).
— The span of the beam (L).
— The eccentricity of prestressing force (e).
— The material properties of the concrete considered were its density (ρ). This was taken as 2400 kg/m^3.

The prestress loss was considered by the loss factor (K). The loading on the beam is considered by the live load acting on it (q_k). This was used to determine the moment variation as illustrated in the next section.

Design Constraints

Given that the weight optimization is achieved by selecting the minimum section properties, the main design constraint relates the section modulus (z_t and z_b) to the moment acting on the member due to the imposed live load alone. Mathematically:

$$z_t \geq \frac{M_v}{(f_{max} - Kf^l_{min})} \quad (2)$$

$$z_b \geq \frac{M_v}{(Kf^l_{max} - f_{min})} \quad (3)$$

where:

$$M_v = \frac{q_k L^2}{8} \quad (4)$$

Whilst equations 2 and 3 provide the lowest permissible value of the section modulus, the initial values of the section modulus for the initial beam provided is to be derived from the formula:

$$z_t = z_b = z = \frac{bh^2}{6} \quad (5)$$

To derive the section properties, the larger section modulus between equations 2 and 3 is used and related to equation 5 to find the smallest possible sections and hence, the minimum weight. For a single-span, simply supported post-tensioned beam it is usually the stresses that govern the behaviour of the beam are constrained by (Eurocode, 2004):

$$\frac{P}{A} - \frac{Pe}{z_t} + \frac{M_{min}}{z_t} = f_t^I \geq f_{min}^I \quad (6)$$

$$\frac{P}{A} + \frac{Pe}{z_b} - \frac{M_{max}}{z_b} = f_b^I \leq f_{max}^I \quad (7)$$

$$\frac{KP}{A} - \frac{KPe}{z_t} + \frac{M_{max}}{z_t} = f_t \leq f_{max} \quad (8)$$

$$\frac{KP}{A} + \frac{KPe}{z_b} - \frac{M_{min}}{z_b} = f_b \geq f_{min} \quad (9)$$

where:

$$M_{min} = \frac{q_k L^2}{8} \quad (10)$$

$$M_{min} = \frac{(q_k + W)L^2}{8} \quad (11)$$

$$\frac{P}{A} - \frac{Pe}{z_t} + \frac{M_{min}}{z_t} = f_{min}^I \quad (12)$$

$$\frac{P}{A} + \frac{Pe}{z_b} - \frac{M_{max}}{z_b} = f_{max}^I \quad (13)$$

$$\frac{P}{A} - \frac{Pe}{z_t} + \frac{M_{max}}{z_t} = f_{max} \quad (14)$$

$$\frac{P}{A} + \frac{Pe}{z_b} - \frac{M_{min}}{z_b} = f_{min} \quad (15)$$

The geometric constraints used were:

$$150 \leq b \leq 300 \quad (16)$$

$$200 \leq h \leq 400 \quad (17)$$

Optimization Model and Required Outputs

Using the previously specified equations, the model was summarized as:

$$\text{Minimize Weight, } W = \rho bhL \quad (18)$$

Subject to:

$$z_t \geq \frac{M_v}{(f_{max} - Kf^I_{min})} \quad (19)$$

$$z_b \geq \frac{M_v}{(Kf^I_{max} - f_{min})} \quad (20)$$

$$\frac{P}{A} - \frac{Pe}{z_t} + \frac{M_{min}}{z_t} = f_t^I \geq f_{min}^I \quad (21)$$

$$\frac{P}{A} + \frac{Pe}{z_b} - \frac{M_{max}}{z_b} = f_b^I \leq f_{max}^I \quad (22)$$

$$\frac{KP}{A} - \frac{KPe}{z_t} + \frac{M_{max}}{z_t} = f_t \leq f_{max} \quad (23)$$

$$\frac{KP}{A} + \frac{KPe}{z_b} - \frac{M_{min}}{z_b} = f_b \geq f_{min} \quad (24)$$

$$150 \leq b \leq 300 \quad (25)$$

$$200 \leq h \leq 400 \quad (26)$$

To find $X = [X_1 X_2]^T$ which minimizes the objective function while satisfying the constraints stated above. Let:

$$b = X_1$$
$$h = X_2$$

Optimization Process

The weight optimization was carried out by replicating the mathematical model in a Microsoft Excel spreadsheet and using the Excel Solver to generate the new optimal solutions.

Development of the Excel Spreadsheet

The objective function, input parameters, design parameters, computed values, constraints and their aforementioned formulas were appropriately placed in the Excel spreadsheet shown in Plate 3.2.

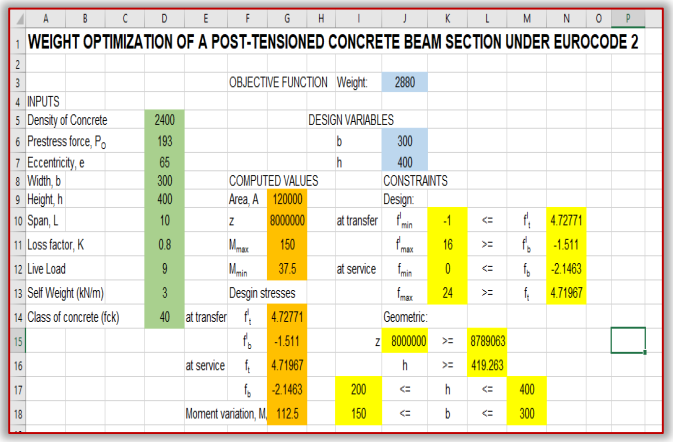

Figure 2: Excel Spreadsheet to perform weight optimization of a post-tensioned beam in development.

Generation of Results

After using the Solver dialogue box to solve the optimization model, the values in the cells containing the design variables were changed due to the success of the operation. This also led to a corresponding change in the weight of the beam. The previous values of both the objective function and design variables are recorded, as well as the corresponding values after the optimization process has been completed.

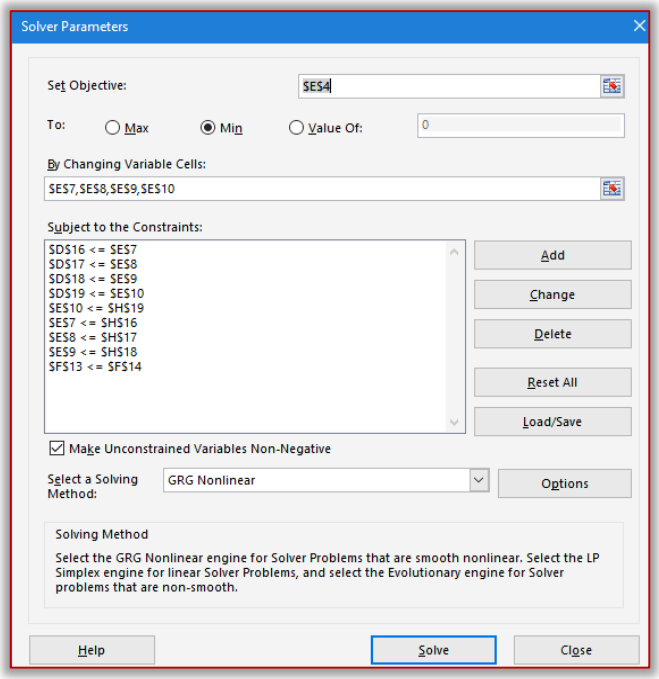

Figure 3: Solver dialogue box with relevant cells filled with information from the spreadsheet.

RESULTS AND DISCUSSION

The model created was used to optimize the weight of a preselected prestressed beam with a span of 10 m, live load of 3 kN/m and prestess loss of 0.8. The initial and final optimal values are given in the Table 1.

Table 1: Results of the weight optimization of the case study.

Design Variable	Original Values	Optimized Values	Gain (%)
h (mm)	250	150	40
b (mm)	350	342.327	2.192
Objective Function	Original Values	Optimized Values	Weight Reduction (%)
Weight (kg)	2100	1232.38	41.3152

The weight reduction and gain were derived from the formulas:

$$\text{Weight Reduction (\%)} = \frac{\text{Original Weight} - \text{Optimal Weight}}{\text{Original Weight}} \times 100\% \quad (27)$$

$$\text{Gain (\%)} = \frac{\text{initial value} - \text{optimal value}}{\text{initial value}} \times 100\% \quad (28)$$

The results of the weight optimization are shown in Table 1. The original weight of the beam was 2100 kg, which was reduced to 1232.38 kg after the resulting weight optimization process was executed. This resulted in a weight reduction of 41.315%.

The dimensions of the beam having been changed in the optimization process, showed both a decrease in height from 350 mm to 342.327 mm and width from 250 mm to 150 mm. The resulting gains from these changes were 2.19% for the height and 40% for the width.

Weight Optimization with Respect to Span Length

Weight optimization was also executed at various span lengths of the beam. Its span was incrementally increased from 5 to 10 meters and weight optimization was performed at each step. The results from the optimization are shown in the Table 2.

Table 2: Weight optimization results with varying span lengths.

Span (m)	Original Weight (kg)	Optimized Weight (kg)	Weight Reduction (%)
5	1440	503.115	65.061
6	1728	724.486	58.074
7	2016	986.106	51.086
8	2304	1440.000	37.500
9	2592	2050.312	20.898
10	2880	2812.500	2.344

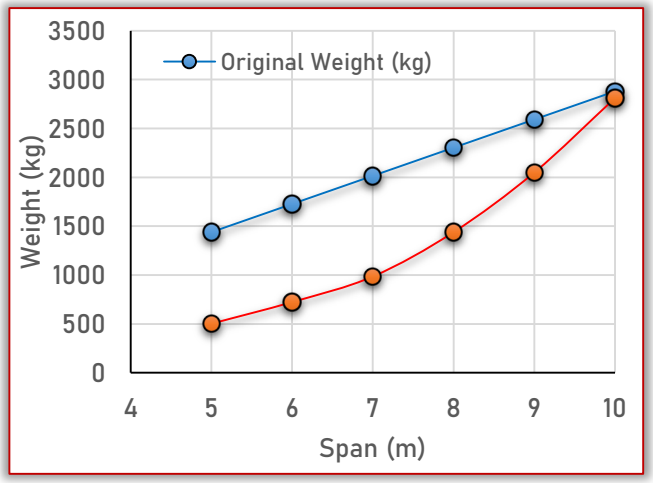

Figure 4: Graph of Span (m) against Weight (kg)

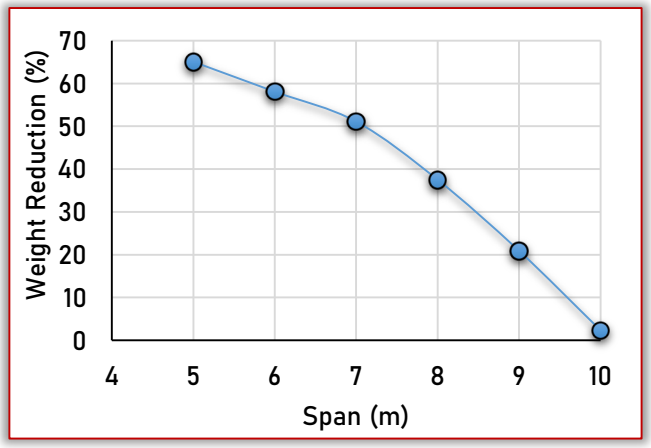

Figure 5: Graph of Span (m) against Weight Reduction (%).

Weight Optimization with Respect to Live Load

Weight optimization was also executed at various live loads imposed of the beam. These were incrementally increased from 3 to 8 kN/m and weight optimization was performed at each step against a constant beam weight. The results from the optimization are shown in Table 3.

Table 3: Weight optimization results with varying live loads.

Live Load (kN/m)	Original Weight (kg)	Optimized Weight (kg)	Weight Reduction (%)
3	2880	1232.376	57.209
4	2880	1423.025	50.589
5	2880	1757.812	38.965
6	2880	2109.375	26.758
7	2880	2460.938	14.551
8	2880	2812.501	2.344

From Figure 6 and Figure 7 respectively, it can be seen that the weight of the beam was kept constant at 2880 kg as the live load imposed on the beam was increased from 3.0 to 8.0 kN/m. The corresponding change from the optimized weight was from 1232.376 kg to 2812.501 kg, which resulted in decrease in the weight reductions from 57.209% to 2.344%.

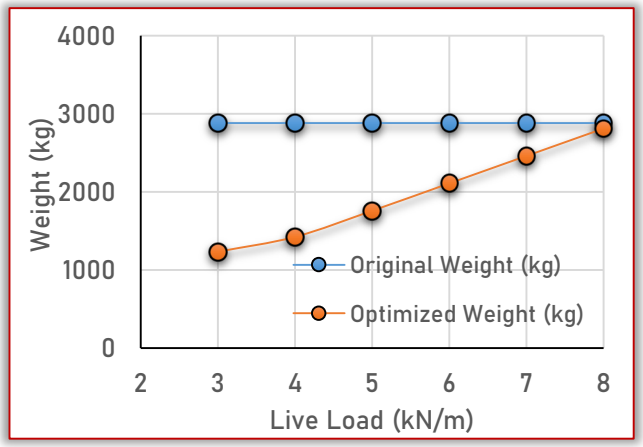

Figure 6: Graph of Live Load (kN/m) against Weight (kg).

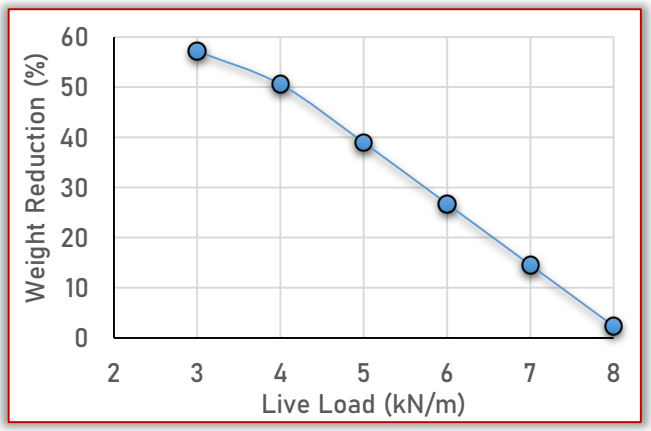

Figure 7: Graph of Live Load (kN/m) against Weight Reduction (%).

CONCLUSIONS

Based on the results obtained from this study, the following conclusions can be drawn:

— An increase in the span length of the beam directly leads to an increase in both the original weight and the optimized weight, with the optimized weight increasing at a greater rate. The optimized weight will eventually match and exceed the original weight as the span length keeps increasing.

- The weight reduction (%) decreases with respect to increasing span length.
- Increasing values of live loads imposed on a beam with the effect of weight optimization lead to an increase in the optimal weight.
- The weight reduction (%) decreases with respect to increasing imposed live load.

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EXAMINING THE MARKET FEASIBILITY OF RESIDENTIAL GREEN BUILDINGS IN TIER–II CITIES WITHIN THE INDIAN CONTEXT: BHOPAL CASE STUDY

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Abstract: The contemporary trend observed among corporate and residential apartments is the adoption of environmentally friendly practices. According to the Indian Green Building Council (IGBC), the demand for green building materials and equipment is projected to reach $8 billion annually by 2025. In line with the global movement towards environmental conservation, this paper evaluate and enhance the level of knowledge pertaining to residential green buildings in Tier II cities in India among developers, customers, and local authorities. The focus of study is Bhopal, a burgeoning residential center located in the heart of India. A comprehensive three–tier survey involving Potential Buyers, Developers, and Government Bodies was conducted to gauge the awareness levels regarding green building concepts among the general public and local real estate developers in Bhopal. The public's willingness to invest in energy efficiency, analyze perspectives on green buildings from customers, developers, and government entities, assess the market potential of residential green buildings, identify challenges faced by developers in green construction, and provide insights into the current scenario of the residential green building market. The findings suggest that effective collaboration among all stakeholders involved in the development of residential green buildings can make them viable for Tier II cities in India.

Keywords: residential green buildings, Tier II cities in India, market feasibility

INTRODUCTION

Green building encompasses practices aimed at enhancing resource efficiency in buildings by minimizing their impact on human health and the environment through improved site selection, design, construction, operation, maintenance, and decommissioning processes. Various types of green buildings are emerging across India, including residential complexes, exhibition centers, hospitals, educational institutions, laboratories, IT parks, airports, government buildings, and corporate offices.

Given India's limited domestic oil reserves and high dependency on imported oil, the country has taken proactive measures to promote green buildings that utilize environmentally friendly designs and materials.

These structures offer a pollution–free environment and lower energy costs through the application of advanced energy management systems, solar technology, high–performance windows, and heat–resistant paints. Solar protection features in green buildings help in reducing heat absorption during the day, thereby decreasing the reliance on air–conditioning systems to maintain comfortable indoor temperatures. Additionally, these features maximize natural light utilization, leading to reduced electricity consumption for lighting purposes and providing thermal comfort for occupants by regulating sunlight exposure throughout the year.

Around the globe, the momentum of green construction is increasing as it is being recognized as a lucrative long–term business prospect. A study carried out by McGraw Hill Constructions across 62 countries, including India, revealed that 51% of professionals in the architecture, engineering, contracting, ownership, and consultancy sectors anticipate that over 60% of their projects will be green by 2015, a substantial rise from 28% in 2012. The expansion of green practices, as identified by McGraw Hill Constructions, is not confined to a specific region or economic condition but is permeating the worldwide construction industry. The Indian Green Building Council (IGBC) forecasts that the market for green building materials and equipment will hit $8 billion annually by 2015. Embracing green practices has emerged as a prevailing trend among both corporate entities and residential complexes. Green construction, characterized by its emphasis on environmental preservation, water conservation, energy efficiency, utilization of recycled materials, and renewable energy sources, has witnessed a significant surge in India, with the number of green projects escalating from 164 in 2009 to over 2000 by 2012.

The primary challenge lies in the lack of awareness regarding Residential Green building design in India. This issue is widespread, with a general lack of awareness among the public and developers leading to widespread

skepticism. Various experts echo the same sentiment about the necessity to address customer perceptions. While incorporating the concept of green building design in project brochures and pamphlets may be a modest beginning, the impact on a broad spectrum of customers is noteworthy. Tackling such issues categorized as myths poses a significant challenge that requires innovative solutions. The Indian real estate sector is largely unorganized, with a wide array of developers ranging from large groups to local entities affecting project quality and customer trust. Insufficient knowledge and reliance on traditional methods are key factors contributing to the misconception surrounding projects like green buildings. Developers must enhance their knowledge base as simply adding greenery in front of a multi–story residential complex does not suffice to classify the building as green. This challenge extends beyond developers, as local development authorities also demonstrate a lack of awareness regarding innovation and new techniques.

The crucial question pertains to achieving this transition in a Tier–II city with a population of around 24 lakh, as India progresses towards a global platform. Conducting surveys with customers aims to gauge their awareness levels and assess their receptiveness to new concepts and innovations. Similarly, engaging with various developers through surveys seeks to evaluate their technical expertise and knowledge in green building construction within the residential real estate sector. Insights gathered from interviews with government officials shed light on the policies and regulatory framework concerning green buildings in residential real estate. The overarching query revolves around the awareness levels among developers and local government bodies. Is it valid to assume that government bodies lack the vision for development? The forthcoming questionnaire will yield data to determine the commercial value and dispel associated myths, serving as a roadmap to evaluate the feasibility of introducing residential green buildings to the Bhopal market. The attitudes of local government bodies will play a pivotal role in shaping the acceptance of new ideas and technologies.

OBJECTIVE OF STUDY

The purpose of this study is to ascertain the necessity of Green Buildings in the current scenario, as advised by consultations from Environmental Planning & Conservation Organisation (EPCO). The study aims to identify challenges linked with Green Buildings, including barriers to entry in Green Building construction, based on consultations from IGBC & Developers. Additionally, the study seeks to conduct a Market Analysis concerning green buildings in the Bhopal region, as per a survey conducted at three different levels.

SIGNIFICANCE OF THE STUDY

It is imperative to contribute to society, as this study stands to benefit customers and developers financially, while also enhancing their understanding of a new concept or innovation. The study primarily focuses on raising awareness among the populace and assessing the readiness of Bhopal citizens to embrace new innovations. Experts have debated the feasibility of green building design, suggesting that widespread acceptance may take up to a decade. The government must take proactive measures to promote such concepts and educate the public about these novel initiatives. Despite government hesitance, it is crucial to engage the public in promoting green buildings to facilitate national progress. This transition can be achieved by incorporating green building principles in the construction of new era buildings. The ultimate goal is to steer the public towards sustainable growth.

Market of developers is poorly organized, with major developers prioritizing brand image and customer satisfaction. There is a need to instill these values in local developers and establish a conducive platform for customer–developer transactions. The key objective is to enhance awareness among local developers to streamline the market. Developers must focus on unconventional concepts and adhere to the guidelines outlined in the Indian real estate act of 2013. Success in projects is contingent not only on market forces but also on developers' efforts to ensure customer satisfaction.

LITERATURE REVIEW

The Concept of Green building: Numerous definitions of sustainable or green buildings exist, with the USGBC (United States Green Building Council) being a prominent advocate of green buildings worldwide. According to USGBC, the term 'green building' is synonymous with 'high performance building,' 'sustainable design and construction,' and other terms that emphasize a comprehensive approach to design and construction. Green building design aims to harmonize environmental stewardship, efficient

resource utilization, occupant well–being, and community integration. According to the Indian Green Building Council (IGBC), a green building is characterized by its ability to operate with optimal energy usage, minimal water consumption, preservation of natural resources, reduced waste generation, and provision of spaces conducive to healthy and comfortable living, in comparison to traditional buildings. The Energy and Resources Institute (TERI), a non–profit organization dedicated to sustainable development, defines a green building as one that is meticulously planned, built, and maintained to decrease overall environmental impacts while simultaneously improving user comfort and productivity.

Some of the key characteristics of sustainable buildings encompass the integration of sustainability considerations in all phases of building design and planning, as well as during the construction and manufacturing of building materials. Sustainable buildings employ healthy and eco–friendly materials and products, along with efficient systems that are easy to maintain and service. These buildings prioritize high functionality, flexibility, adaptability, user health, and comfort, while also emphasizing aesthetic and urban design quality with high public acceptance. Furthermore, they are strategically located with convenient access to public transportation services and networks.

Conventional construction methods typically involve substantial quantities of non–renewable and toxic materials, with little regard for the environmental impact of the building. In contrast, green buildings mitigate these impacts, offer improved health benefits, and consume less energy, resulting in long–term cost savings. The design of green buildings is a pragmatic and environmentally conscious approach, considering factors such as geographical location, climatic conditions, use of locally available materials with low embodied energy, and specific design parameters based on building usage. By adopting such an approach, green buildings minimize harm to the environment throughout their lifecycle. When clustered together, green buildings form green zones that promote a healthier environment, reduce the heat–island effect, and ultimately contribute to significant energy savings and a lower global carbon footprint at the city and national levels. Sustainable buildings overall consume less energy and water, emit fewer greenhouse gases, use materials more efficiently, and generate less waste than conventional buildings over their entire lifespan.

Compulsions of going green:

Research indicates that the global urban population is projected to increase from 47% in 2000 to 70% in 2050. Specifically, the urban populations of China and India are expected to grow substantially, exceeding one billion in each country by 2050. In India, rapid urbanization is primarily attributed to a combination of socio–political factors. In accordance with the expanding development and population, the building sector of India is anticipated to experience a five–fold growth by the year 2050, considering that two–thirds of the commercial and high–rise residential structures projected for 2030 are yet to be constructed (70%). The total energy demand of India is forecasted to increase by 6.5% annually until 2016–17 to support the country's expected growth rate. Consequently, India is on track to become the world's second largest emitter of greenhouse gases. It is widely acknowledged that green buildings play a crucial role in conserving resources throughout the entire lifecycle of a structure, with the process commencing from Green design.

Green design embodies environmental, economic, and social aspects that bring benefits to all stakeholders, such as owners and occupants. The rapid advancements in construction methodologies and principles indicate that numerous modern office buildings in metropolitan cities across India are already incorporating various Green features into their structures prior to occupation. Amidst such circumstances, it is imperative that residential developments also transition towards green development to tackle forthcoming challenges related to energy efficiency, heightened pollution, escalating carbon footprint, and emissions. Embracing green practices will ultimately lead to the sustainable advancement of society, the nation, and the global community as a whole.

Benefits of Sustainable Building:

The impact of buildings on the environment, human well–being, and the economy is substantial. The effective adoption of green building techniques can optimize both the economic and environmental performance of buildings. Ongoing research aims to identify and elucidate the myriad benefits and costs associated with green building, as well as how to attain maximum benefits at minimal costs.

According to the Indian Green Building Council (IGBC), green building offers a plethora of advantages including environmental benefits such as emissions reduction, water conservation, stormwater management, temperature moderation, and waste reduction. Moreover, green building presents economic benefits such as energy and water savings, increased property values, reduced infrastructure strain, enhanced employee attendance and productivity, sales enhancements, and the development of a local talent pool. Additionally, social benefits like improved health are also associated with green building practices.

- **Economic and Market Aspects of Green Building:**

Recent studies suggest that enhancing energy efficiency in buildings and appliances could result in a reduction of 1.6 gigatons of CO2 emissions by 2020 and up to 7 gigatons by 2050. An estimated $158 billion annually between 2010 and 2050 is needed to disseminate energy efficiency technologies worldwide. Research by McGraw Hill Construction indicates that approximately half of new global commercial building projects are expected to adopt green building principles, while 45% of retrofit projects on existing buildings are geared towards enhancing energy performance. Asia emerges as the swiftest growing green building market region, with the number of firms primarily dedicated to green building projected to surge from 36% presently to 73% by 2013. More than half of the surveyed firms anticipate a significant focus on green building, with over 60% of their projects falling into this category, an increase from the current 30%. Furthermore, more than 85% of the firms foresee rapid or consistent growth in sales and profits associated with green building.

- **Challenges of Embracing Sustainable Practices:**

Research indicates that the global urban population is anticipated to rise from 47% of the total population in 2000 to 70% by 2050. Notably, the urban populations of China and India are predicted to continue growing rapidly, surpassing one billion in both countries by 2050. In India, the substantial urbanization trends stem from a combination of socio–political motivations. The Green building movement in India has experienced significant growth over the past 3–4 years, ever since the CII–Godrej GBC initiated its pursuit of the prestigious LEED rating for its center in Hyderabad. The achievement of a Platinum rating for this building has sparked considerable enthusiasm throughout the country, leading to a surge in various green building projects including residential complexes, exhibition centers, hospitals, educational institutions, laboratories, IT parks, airports, government buildings, and corporate offices.

Motivated by a desire to demonstrate environmental awareness, numerous commercial facilities have integrated "Green technologies" to obtain certifications for being "Green and Sustainable." The Green Buildings Ratings and Certification process, as outlined by USGBC, has gained significant traction in recent years, with a notable increase in projects certified by rating systems like Energy Star and LEED. In India, the Indian Green Building Council (IGBC) offers LEED ratings and aims to position the country as a leader in green buildings by 2015. The Green rating for Integrated Habitat Assessment (GRIHA), India's National Rating System, was developed by The Energy and Resources Institute (TERI) in collaboration with the Ministry of New and Renewable Energy. This system evaluates the design of green buildings across various climatic zones in India. Mumbai had the highest number of registered green building projects among Indian cities in 2008, reflecting a growing awareness and interest in eco–friendly constructions. The IGBC reported a total of 315 green buildings in India in 2008, with 250 of them being commercial properties.

The Kyoto Protocol is an international agreement associated with the United Nations Framework Convention on Climate Change, requiring Parties to adhere to globally binding emission reduction targets. Carbon credits and carbon markets play a crucial role in national and international efforts to mitigate the rise in greenhouse gas (GHG) concentrations. In certain markets, one carbon credit is equivalent to one metric tonne of carbon dioxide or its equivalent in other greenhouse gases.

Carbon trading involves the utilization of an emissions trading strategy whereby greenhouse gas emissions are restricted, and markets are employed to distribute these emissions among a group of regulated sources. The generation of carbon credits can serve as a viable source of revenue for rural areas and industrial sectors by reducing GHG emissions or implementing environmentally friendly practices such as tree planting, which is feasible for the Indian populace. The promotion and dissemination of

knowledge regarding such business opportunities should be facilitated through the educational system. In India, the concept of constructing energy–efficient 'green' buildings may seem appealing theoretically, but its practical implementation, particularly in developing nations, can be prohibitively costly. Unfortunately, there are no direct incentives in India for the construction of energy–efficient residential or commercial structures. The real estate services specialist Jones Lang LaSalle notes various challenges faced by the Indian housing industry in its efforts to adopt eco–friendly practices. A significant obstacle is the diminishing overall demand for space in Indian urban areas. By 2014, it is projected that India's major cities will encounter approximately 25 percent vacancy rates, posing a challenge for developers to find tenants or buyers willing to pay premium prices for environmentally sustainable spaces. Private homeowners lack immediate motivation to embrace energy–efficient measures due to the absence of mandatory standards for green buildings in India. Most municipalities do not possess uniform and practical energy codes, specifically for passive and solar designs. Furthermore, there is a lack of clear implementation guidelines for state and municipal bodies to establish and enforce building energy efficiency programs and policies. The absence of an effective local infrastructure for code administration and enforcement, including inspections, contributes to building owners' reluctance to invest in green technologies and energy efficiency during construction. Developers often refrain from investing in building energy efficiency since they do not directly benefit from these initial expenditures, ultimately passing on the inefficiency costs to tenants and the environment. The high current borrowing costs act as a significant barrier to securing incremental funds for efficiency improvements, despite the potential future energy cost savings. Bhopal, recognized as an emerging Tier–II residential hub, serves as the capital of the Indian state of Madhya Pradesh and the administrative center of Bhopal district and division. Renowned as the "City of Lakes" due to its natural and artificial water bodies, Bhopal stands out as one of India's greenest cities. Divided into old and new Bhopal, the city accommodates various national institutions and installations, including ISRO's Master Control Facility, AIIMS Bhopal, and NIFT. Bhopal gained global attention following the tragic Bhopal disaster in 1984, caused by a gas leak at a Union Carbide India Limited plant. Since then, the city has been a focal point for protests and campaigns, drawing participation from worldwide supporters. Additionally, Bhopal is celebrated for its exquisite silver jewelry, intricate beadwork, and embellished velvet accessories.

In recent times, Bhopal has emerged as a promising real estate destination subsequent to Indore in the state of Madhya Pradesh. It presents diverse investment prospects for both real estate developers and investors. The economic landscape of Bhopal predominantly consists of the prominent electrical entity BHEL, along with service and administrative sectors. The progression of real estate in Bhopal appears to be embracing a comprehensive approach as all sectors, whether residential, commercial, or retail, are experiencing rapid growth. The research methodology adopted encompasses the utilization of both Primary and Secondary data. The secondary data encompasses information sourced from publications such as journals, magazines, books, and the internet. On the other hand, the primary data is acquired through the administration of questionnaires across three distinct categories. Specifically, three separate questionnaires were formulated targeting Potential Buyers, Developers, and Officials affiliated with EPCO (Environmental Planning & Conservation Organization). All questionnaires were structured in a non–disguised format. The sample size for potential buyers was set at 200, while for Developers it was 10. The sample size for EPCO officials was determined as 2 based on governmental availability. It is noteworthy that the sample size was deliberately limited as the study is confined to the Bhopal region.

The interpretation of the findings derived from the three–tier survey reveals several key conclusions. From the perspective of potential buyers, it was observed that 20% exhibit a comprehensive understanding of the green building concept, whereas nearly 50% possess a moderate awareness of the same. The majority of potential buyers fall within the age brackets of 18–35 years and 35–49 years, with the most informed individuals belonging to the former group. Furthermore, a large portion of potential buyers hail from the middle and upper middle class, with 47% falling within the income range of Rs. 2–5.9 LPA and 42% falling within Rs. 6–12 LPA. Print media emerges as the primary source of

awareness regarding green buildings, accounting for 42%, while social media contributes 10% to the awareness pool. Notably, burgeoning areas in Bhopal such as Hoshangabad Road, Ayodhya Bypass, and Arera Colony Extension attract considerable customer interest at rates of 30%, 22%, and 28% respectively. A significant 40% of potential buyers harbor misconceptions regarding the green building concept.

From the perspective of the developers, it is noted that a significant percentage, specifically 80%, have acquired knowledge regarding the concept of green building, yet have not implemented it practically. Furthermore, a vast majority, around 90%, are currently employing various sustainable practices such as rainwater harvesting, renewable energy sources, natural lighting, and water recycling techniques in their projects. However, there exists a reluctance among 30% of developers to embrace green building technology due to regulatory concerns, while 40% refrain from opting for it because of market–related issues. Additionally, 50% of developers express hesitance towards green building technology due to the intricate nature of information and the complex guidelines necessary for obtaining green certifications. Another 40% abstain from green development owing to the substantial initial investment linked with green construction. The primary source of awareness among potential buyers regarding green building concepts predominantly stems from print media, accounting for 42%, followed by social media with a share of 10%.

It is noteworthy that a staggering 90% of developers believe that governmental bodies such as the Government and City Administration should play a crucial role in promoting green development within the residential real estate sector. Half of the developers advocate for the government's active involvement in fostering awareness about green building concepts among the general populace. Shifting focus to the Government's perspective, the Government of Madhya Pradesh is currently engaged in collaboration with EPCO, BDA, and BMC towards establishing a Clean Development Management Agency in Bhopal. This agency aims to tackle issues related to sustainable development and facilitate the growth of green homes within the city. Officials opine that revising the existing guidelines and rating systems to be more developer–friendly is essential to promote green building development in the residential real estate sector. Moreover, there is a discernible potential for residential green development in the near future as per the officials' viewpoint. The Government of Madhya Pradesh is poised to launch initiatives promoting sustainable development and green building technology to enhance public awareness.

In conclusion, the burgeoning development across various realty sectors has led to a notable surge in property prices in Bhopal. Notably, prices in prime locations have witnessed a significant increase due to the real estate growth in the city. The residential sector has seen the emergence of both luxury villas and affordable housing options, diversifying the housing landscape in Bhopal. With the property market in Bhopal gaining traction and national developers showing interest in the city, there is a growing focus on realty development. As the city transitions through a dynamic phase of real estate growth, the need for residential green building development becomes increasingly evident. Cooperation among all stakeholders involved in the process can pave the way for feasible residential green buildings in Bhopal. By considering the insights presented in this project report, the vision of establishing green homes in Bhopal can undoubtedly be realized.

CONCLUSIONS

Based on the Analysis and Interpretation, the subsequent set of recommendations is presented to enhance the feasibility of residential green building development in the Bhopal region:

To foster awareness among the general public regarding green building development, it is imperative to devise an efficacious promotional strategy and campaign targeting the predominant demographic of potential buyers, specifically individuals within the middle to upper–middle class aged between 18–49 years. The promotional strategy must encompass all facets of green building construction and development to ensure comprehensive customer awareness and prevent developers from exploiting customers unlawfully. The primary source of awareness is print media, closely trailed by the internet and social media. Considering that a substantial portion of potential buyers fall within the 18–49 age bracket, which also constitutes the primary users of internet and social media, the promotional strategy should emphasize the utilization of internet and social media as potent promotional tools for the green building concept.

The Government of Madhya Pradesh should take part in conducting training programs for developers and engineers to equip them with the requisite technical knowledge associated with green building construction. Furthermore, the Government should incentivize partial funding for green building projects to facilitate developers in establishing green residential projects and instil a sense of trust in potential buyers towards green home projects due to governmental involvement. The Green Building Principles (GBPs) and Rating Systems for Green should be reinstated and structured favourably for developers to encourage investments in green residential development projects. Collaboration among various governmental entities such as the Bhopal Municipal Corporation (BMC), Environmental Planning & Conservation Organisation (EPCO), Bhopal Development Authority (BDA), local developers, and Non–Governmental Organizations (NGOs) is essential to ensure seamless coordination in facilitating the feasibility and success of residential green building development in the foreseeable future.

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INFLUENCE OF TEMPERATURE ON THE MEASUREMENT OF TOTAL DISSOLVED SOLIDS (TDS) IN WATER

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Abstract: Mostly, surface waters do not have properties that meet consumer requirements due to their circuit through the environment that contaminates them with dissolved and suspended substances. Their content of total dissolved solids (TDS) is an indicator of quality, giving taste and smell to the water. This study aims to investigate the variation of total dissolved solids (TDS) with the temperature of a water sample. For the experiment, unfiltered water was collected from a spring. During the heating of the water sample on an electric hub, the temperature and TDS values were recorded with digital meters. The increase in the concentration of TDS with temperature was observed quantitatively.

Keywords: total dissolved solids (TDS), electrical conductivity meter, water quality

INTRODUCTION

Substances that can be dissolved in surface waters, having a size of less than one micron, can be: *mineral substances* (chlorides, carbonates and bicarbonates, sulfates, oxides, sodium nitrates, potassium, calcium, magnesium, iron, silicon), *organic substances* (plant and animal residues, compounds containing carbon, hydrogen and sometimes oxygen and nitrogen) or *gases* (oxygen, nitrogen, carbon dioxide, methane, hydrogen sulfide) [1]. The ions of these substances give the electrical conductivity of water that increases as their concentration is higher [1, 2]. Also, an increase in water temperature leads to a decrease in viscosity and an increase in mobility and number of ions (due to the dissociation of molecules), which will increase electrical conductivity [2]. Moreover, the solubility of certain substances in water may change, which will have the effect of increasing the value of total dissolved solids (TDS) in water [3]. Thus, a directly proportional dependence was observed between the water temperature and the values of electrical conductivity and TDS [1, 3].

Several papers address the influence of temperature on the TDS level in water. For example, the work of B.B. Wang [1] focuses on lowering TDS in tap water by several methods. By the heating method, the 1L samples are heated to different temperatures and observed during cooling for up to 1 hour, with data for longer durations being estimated. It has been observed that TDS values decrease with a decrease in temperature. From the studied heating range of 40°C–100°C, the maximum TDS value was recorded at 60°C. In this experiment, the difference between the TDS values at maximum and initial temperature is 58.42 ppm (from 204 ppm at 60°C, the TDS value decreases to 145.58 ppm at 26.9°C after 94.8 min.). The author concluded that the temperature range of 40°C–60°C is optimal for reducing TDS (the largest experimentally observed decrease in TDS is 16% at 50°C), rather than heating to a higher temperature.

A.T. Ahmed et al. [4] analyzed the impact of temperature on the quality of drinking water stored in plastic bottles. Their experiments consisted in heating water in plastic bottles from room temperature (20°C) up to 30°C, 50°C, and 70°C by three heating methods (sun, oven, and microwave). Among the physicochemical properties analyzed, TDS measurements showed a direct relationship with temperature increase. The authors reported that increased heating and exposure to sunlight leads to increased TDS of bottled water samples due to the release of heavy metal ions into the water.

S. P. Fitri et al. [5] conducted experiments on a reverse osmosis (RO) desalination plant equipped with a solar thermal collector. An increase in TDS levels was also observed due to an increase in TDS in the raw feed water after the heating process in the solar collector at 31°C, 35°C and 40°C, respectively. They concluded that the best results regarding the quality of the TDS water product, the amount of water produced and the ability to repel salt were obtained at lower temperature.

So, determining the TDS level as a function of water temperature is of interest not only in terms

of the taste of drinking water [1, 4], but also the implications of increasing TDS in high–temperature water applications such as water boilers or other industrial processes [5].

According to the Romanian standard STAS 4706–88, given their use, surface waters (natural or landscaped watercourses, natural lakes and reservoirs) are classified into three quality categories, for which the TDS accepted levels are presented in table 1.

Table 1. TDS levels of surface waters in accordance with STAS 4706–88

Quality category	Designated use of surface water	TDS in ppm (mg/L)
I	centralized supply of drinking water and livestock units, food industry, certain irrigation, fish farming (for salmonids), swimming pools	750
II	industry, fish farming (except salmonids), leisure and urban needs	1000
III	irrigation, supplying hydropower plants, cooling aggregates, supplying washing stations	1200

In table 1, the TDS values were determined as dry filterable residue (fixed residue) at 105°C. The EPA recommends that the TDS level for drinking water be below 500 ppm (mg/L) [6]. At TDS levels greater than 1000 ppm (mg/L) water becomes unpalatable [6].

The TDS level in water can be determined with digital meters (conductivity method) [4, 7–10] or measured in the laboratory under standardized conditions (gravimetric method) [11]. Determinations made with digital meters have several advantages such as: quick direct on–site measurement, detects and provides the value of dissolved solids in a sample without involving further data processing or sample preparation, high degree of precision and accuracy [12].

This study aims to quantitatively determine the dependence between water temperature and total dissolved solids (TDS). TDS measurements were performed with a digital meter during heating the water sample on an electric hob. TDS and temperature variations with heating time were recorded at 1–minute intervals.

MATERIALS AND METHODS

In order to study the influence of the temperature on the TDS level in water, the water sample was collected from an unfiltered source, i.e. from a natural spring. This is because springs are known to have higher levels of TDS than other sources, e.g. tap water [1], and its dependence on temperature can be better observed in a laboratory experiment. So, a sample of 500 ml of spring water was heated in a beaker on an electric hob.

Figure 1 shows a photo of the experimental setup. A digital thermometer and TDS meter were used to measure the temperature of the water sample (in °C) and total dissolved solids (in ppm) during heating, at 1–minute intervals. The meters were suspended in the water sample using a tripod with a clamp so that the immersion level of the TDS meter was respected. The temperature sensor has been positioned at the same height.

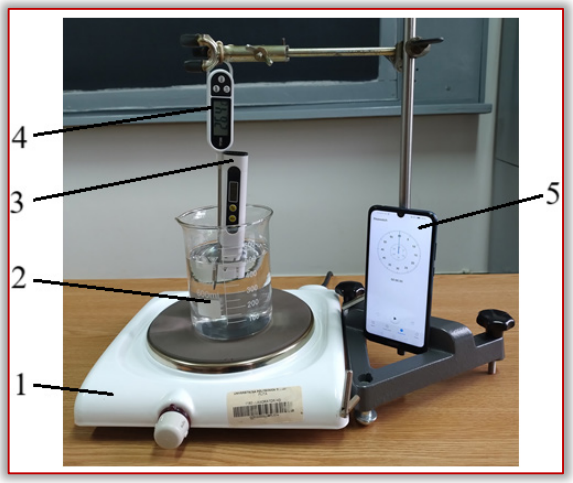

Figure 1. Photograph of the experimental setup: 1 – electric hob, 2 – beaker of 600 ml, 3 – digital TDS meter, 4 – thermometer, 5 – stopwatch.

The TDS meter works by measuring the electric current passing through the water sample between two titanium alloy electrodes, as an indicator of the number of ions existing. Electrical conductivity (in µS/cm) is converted to ppm units and displayed (conversion factor is 0.5 for NaCl standard calibration) [13].

A maximum heating temperature of 60°C was chosen due to the TDS meter's automatic temperature compensation range (ATC= 0÷60°C). At level 3 of 6 of the electric hob this temperature was reached after about 20 minutes of heating. This is the temperature up to which the TDS meter is calibrated to adjust the readings according to the temperature of the sample [2, 13].

The TDS meter adjusts readings taken at a certain temperature as if they were taken at a standardized temperature of 25°C [13].

RESULTS AND DISCUSSION

Table 2 shows the experimental results of temperature and TDS level in the water sample obtained as a function of heating time. Figure 2 and 3 show the graphical representation of these results.

In Figure 2, a polynomial trend line of order 4 (R^2 = 0.74) was used to best match the experimental values of TDS with the heating time, while in Figure 3, a linear trend line (R^2 = 0.97) proved to

be the most suitable for the variation of water temperature over time.

Table 2. Experimental values

Time (min.)	TDS (ppm)	Temp. (°C)
0	478	26.2
1	478	26.2
2	478	26.9
3	498	28.6
4	519	30.5
5	541	33.5
6	541	36.8
7	541	40
8	541	42.1
9	515	44.3
10	515	46
11	515	47.5
12	531	48.7
13	531	50
14	531	51
15	531	52.1
16	531	52.9
17	531	54.8
18	531	56.5
19	531	57.8
20	531	59.3

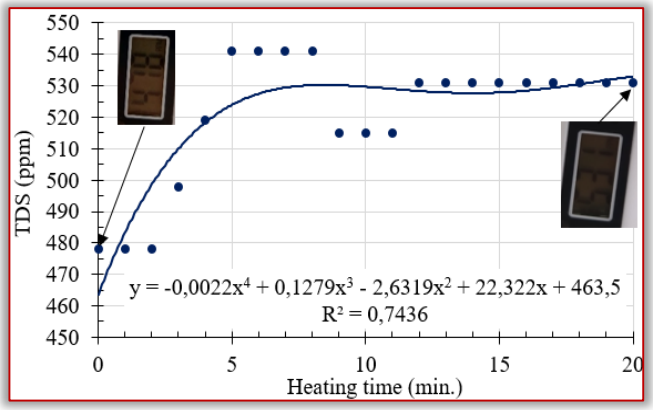

Figure 2. TDS variation vs. water sample heating time

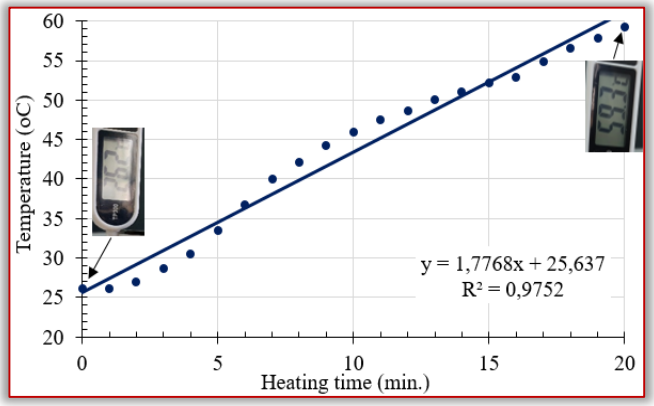

Figure 3. Temperature variation vs. water sample heating time

As can be seen from Figure 2, the TDS level in the water sample increases with heating time, from 478 ppm at 26.2°C to 531 ppm at 59.3°C. For the entire heating range, this represents a 10% increase in the TDS level (53 ppm for the entire range). A gap between 9 to 11 minutes of heating is observed, where the TDS level decreases, after which a constant value of 531 ppm is measured until the end of the experiment up to 20 min. After approx. 5 min. of heating, bubbles (dissolved oxygen and other gases) appeared in the volume of the water sample and probably adhered to the surface of the TDS meter electrodes that affected the readings.

Although constant mixing of the water sample was carried out during heating, the area near the electrodes was inaccessible. It is known that external factors, such as bubbles formed in the solution between the electrodes, can decrease TDS meter readings [13].

CONCLUSIONS

TDS level in water is a quality indicator which can be determined in standardized laboratory conditions by evaporation or by digital meters which are simple to use and reliable if are calibrated [7]. Certainly, high–precision measurements must be carried out under laboratory conditions.

Practical methods of removing TDS from water include: reverse and forward osmosis, nanofiltration, distillation, ultrafiltration, precipitation, desalination, electrocoagulation, ion exchange, electrochemical technologies, electrodialysis, adsorption, crystallization, and deionization [1, 14].

The proposed laboratory experiment aimed to quantitatively determine the direct proportional dependence between the TDS level in water and temperature, both measured with digital meters. Increasing the temperature from 26.2°C to almost 60°C, a 10% increase in the TDS level was observed.

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INCORPORATING INTERNET OF THINGS (IOT) AND BIG DATA ANALYTICS IN THE DEVELOPMENT OF SMART BUILDINGS IN THE ROMANIAN CONTEXT

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Abstract: The creation of optimal solutions for smart buildings (or intelligent buildings) is underpinned by information technologies that integrate the Internet of Things (IoT) and utilize Big Data Analytics to decrease costs, improve energy efficiency and reliability, and offer personalized experiences based on the preferences of the occupants. Smart building management systems (BMS) integrate an array of sensors, actuators, and specialized networks, all controlled through a centralized system, to monitor room conditions and implement automated protocols aimed at maintaining or enhancing comfort while optimizing energy usage. Big Data Analytics for smart buildings involves the use of advanced analytical techniques and tools to process, analyze, and derive meaningful insights from the vast amounts of data generated within smart building systems. The integration of Big Data Analytics in smart buildings allows for informed decision–making, predictive maintenance, and the implementation of data–driven strategies to optimize building performance and create more sustainable and responsive building ecosystems. This article will explore the applications of the Internet of Things (IoT) and Big Data Analytics within academic and industry contexts for smart buildings, covering both the construction and operational phases. It will emphasize the priorities, applications, and benefits of these technologies in the realm of smart building systems in the Romanian context.

Keywords: Big Data Analytics, Internet of Things (IoT), IoT challenges, smart buildings

INTRODUCTION

Buildings constitute fundamental and essential components of the human living environment. The inception of smart buildings can be traced back to the 1970s, marked by the introduction of the first building automation systems designed to monitor and control various building systems like lighting, heating, and air conditioning.

The concept of smart buildings has emerged from the growing integration of advanced technologies into building systems and plays a pivotal role in the enhancement of cities and infrastructures, primarily focusing on improving the comfort of residents. This integration allows for the remote control and management of a building's entire life cycle, aiming to enhance comfort, convenience, and energy efficiency while optimizing costs.

On the other hand, they contribute to superior energy efficiency, oversee safety aspects, and establish an improved framework for comfort, quality of life, and services tailored to the preferences of both residents and businesses [1].

The convergence of smart buildings and advancing technologies has unlocked a lot of opportunities to improve different facets of building management and security. Deploying applications like energy optimization, streamlining building management, enhancing resident comfort, managing reactive alarms, ensuring personal and asset protection, and handling intrusion events signifies a significant stride toward establishing more intelligent and secure living and working environments [2,3]. Intelligent management systems contribute to the smart building paradigm by enhancing features such as automation, optimization, and security protocols.

The evolution of smart buildings has experienced a notable acceleration, particularly with the introduction of Internet of Things (IoT) technology [4–8]. Also, Big Data Analytics plays a pivotal role in the design and functioning of smart buildings, providing a lot of advantages in optimizing efficiency, bolstering sustainability, fortifying security, and delivering personalized experiences. Nevertheless, storing and searching massive data in real–time is a complex and laborious task for smart buildings. This advancement has resulted in the development of more sophisticated and interconnected building management systems.

By focusing on IoT and Big Data Analytics, the study seeks to provide insights into how these technologies are intertwined and contribute synergistically to the development, management, and optimization of smart buildings. The review will encompass key findings, challenges, and emerging trends in the intersection of IoT and Big Data Analytics within

the realm of smart buildings in the Romanian context.

THE INTEGRATION OF IoT IN SMART BUILDING TECHNOLOGIES

In the contemporary landscape, the IoT ecosystem transformed traditional buildings and has evolved into a comprehensive network comprising a diverse array of devices, sensors, and systems meticulously designed to seamlessly collect and exchange data. This intricate interconnectivity empowers smart buildings by fostering automation, facilitating data–driven decision–making processes, and ushering in unprecedented levels of operational efficiency. The integration of these technologies not only enhances the functionality of individual components but also converges them into a cohesive framework, allowing smart buildings to adapt dynamically to changing conditions, optimize resource utilization, and prioritize sustainability. This holistic approach to IoT in smart buildings signifies a transformative shift towards intelligent, and responsive environments, optimizing resource utilization and fostering sustainability [9–11].

In the realm of smart buildings, an intelligent system typically functions through three hierarchical levels:

— data infrastructure level (this encompasses the myriad data sources within the building that serve as the foundation for the intelligent system's operations);
— system infrastructure level (that serves as the central component of the intelligent system and enables leveraging the collected data for various purposes);
— service level (that encapsulates the array of services provided by the intelligent system to various stakeholders, including building managers, residents, energy suppliers, and others, enhancing overall operational efficiency).

The Heating, Ventilation, and Air Conditioning (HVAC) system plays a vital role in ensuring that an intelligent building maintains optimal conditions for occupants by providing sufficient heating, effective ventilation, and improved air conditioning [12–14].

The IoT architecture is designed to equip all objects with identification, detection, networking, and processing capabilities to achieve integrated ambient intelligence. This enables objects to interact, share information, and develop advanced services over the Internet facilitating several key capabilities:

— comprehensive understanding;
— context–sensitive decision–making; and
— intelligence autonomy.

Furthermore, the implications of IoT encompass two key aspects:

— integration into everyday objects, and
— formation of interconnected networks.

The architecture of the Internet of Things (IoT) facilitates the smooth transition of data from the physical realm to the digital domain, being commonly depicted as a four–stage process, known as the IoT data flow:

— sensing/perception stage;
— communication/network stage;
— data processing and analysis stage;
— cloud/storage stage. This orchestrated flow of data enables the extraction of valuable insights and empowers stakeholders to take informed actions based on analysis outcomes.

The integration of IoT in smart buildings revolutionizes how they are designed, operated, and experienced by occupants, yielding a multitude of applications, such as:

- Energy Management: IoT–enabled sensors can monitor energy consumption in real–time, allowing for optimized usage patterns, predictive maintenance of HVAC systems, and efficient allocation of resources to minimize waste;
- Occupant Comfort and Safety: Smart sensors can adjust lighting, temperature, and ventilation based on occupancy levels and preferences, ensuring a comfortable and safe environment for building occupants. Additionally, IoT devices can detect potential hazards such as gas leaks or fire outbreaks and trigger timely alerts or automated responses;
- Facility Management and Maintenance: IoT sensors can track equipment performance, predict maintenance needs, and schedule repairs proactively to minimize downtime and prolong the lifespan of building assets. Remote monitoring capabilities also enable facility managers to oversee operations from anywhere, improving overall efficiency;
- Security and Access Control: IoT–enabled surveillance cameras, motion sensors, and access control systems enhance security by monitoring building perimeters, detecting unauthorized access, and issuing alerts in case of suspicious activities. Integration with smart locks and biometric authentication further strengthens access control measures;

- Space Utilization Optimization: By analyzing data on occupancy patterns and space usage, IoT solutions can optimize office layouts, meeting room allocations, and resource utilization to maximize efficiency and productivity;
- Environmental Monitoring and Sustainability: IoT sensors can monitor air quality, humidity levels, and environmental conditions to ensure compliance with health and safety standards. Additionally, real–time data analytics enable building managers to identify opportunities for energy conservation and implement sustainable practices;
- Predictive Analytics and Decision Support: By leveraging IoT–generated data, machine learning algorithms can forecast future trends, anticipate maintenance needs, and provide actionable insights for informed decision–making, thereby improving operational performance and cost–effectiveness.

BIG DATA INTEGRATION IN SMART BUILDING TECHNOLOGIES

The integration of big data in smart building technologies represents a pivotal advancement in the realm of modern architecture and infrastructure management. This synergy harnesses the power of large–scale data analytics and intelligent systems to optimize various aspects of building operations, enhance occupant comfort, and improve overall efficiency. At its core, big data integration in smart buildings involves the collection, storage, analysis, and utilization of vast amounts of data generated by sensors, devices, and systems embedded within the building environment. These sensors capture real–time information on factors such as occupancy patterns, energy consumption, environmental conditions, and equipment performance.

Through sophisticated data analytics techniques, this wealth of information is processed and analyzed to derive actionable insights and inform decision–making processes. Moreover, big data integration facilitates the implementation of advanced management strategies such as demand response and predictive maintenance. By analyzing historical data and trends, building managers can anticipate peak energy demand periods and adjust operations accordingly to reduce costs and minimize strain on the grid. Predictive maintenance algorithms identify potential equipment failures before they occur, enabling proactive repairs and minimizing downtime. Additionally, big data integration enables enhanced security and safety measures within smart buildings. By aggregating data from surveillance cameras, access control systems, and environmental sensors, potential security threats and safety hazards can be quickly identified and addressed.

For instance, anomalous behavior patterns can trigger alerts for security personnel, while environmental sensors can detect fire or gas leaks and initiate appropriate emergency responses.

By harnessing the power of data analytics and intelligent systems, smart buildings can achieve unprecedented levels of efficiency, sustainability, and occupant satisfaction, shaping the future of urban living and infrastructure management [15–17].

RESEARCH METHODOLOGY

In this research, the principal approach to data gathering involved administering a questionnaire survey to capture information on the attitudes, perceptions, experiences, and practices of construction practitioners. By delving into these variables, the study aimed to elucidate the perspectives of industry stakeholders, prevailing challenges, and potential areas for enhancement concerning the incorporation of the Internet of Things (IoT) and Big Data Analytics in the development of smart buildings in the Romanian context.

Through the method of random sampling, the study selected 50 participants from diverse backgrounds within the civil engineering sector in Romania. This sample included CEOs, managers, and experts from various technical and economic levels, comprising 34 men and 16 women in senior positions. The data gathered from these participants can provide valuable, data–driven insights that have the potential to inform policy decisions, shape industry practices, and guide future research efforts within the Romanian construction sector. It's essential to note that all participation in the study was voluntary, and participants were fully informed about the study's objectives and the confidentiality of their responses.

The use of semi–structured interviews allowed for a balanced approach, offering some predetermined questions while also granting participants the freedom to elaborate on their responses and provide additional insights. This methodology ensured a comprehensive exploration of the participants' perspectives, experiences, and challenges within the civil engineering industry, contributing to a robust

and nuanced understanding of the sector's dynamics.

The following questions focusing on smart buildings were addressed to the participants:

Q1) General understanding:

— How would you define a "smart building" within the context of the civil engineering industry?
— What are the key components or features that distinguish a smart building from a traditional one?
— How familiar are you with the current trends and advancements in smart building technologies?

Q2) Implementation and integration:

— Have you been involved in any projects related to the design, construction, or retrofitting of smart buildings?
— What challenges have you encountered during the implementation of smart building technologies?
— How do you ensure seamless integration of various smart systems within the building infrastructure?

Q3) Technology and innovation:

— Which smart building technologies do you consider most promising or impactful in the Romanian market?
— How do you prioritize the selection of smart technologies for a specific project?
— What role do you see emerging technologies like IoT, AI, and data analytics playing in the future of smart buildings?

Q4) Regulations and standards:

— Are there specific regulations or standards governing the implementation of smart building solutions in Romania?
— How do you ensure compliance with these regulations while incorporating innovative technologies?
— What changes or improvements would you suggest to existing regulatory frameworks to better support smart building initiatives?

Q5) Operational efficiency and maintenance:

— How do smart building technologies contribute to improving operational efficiency and reducing maintenance costs?
— What strategies do you employ to optimize the performance of smart building systems over their lifecycle?
— How do you address security and privacy concerns related to the data generated by smart building systems?

Q6) Market dynamics and future outlook:

— How do you perceive the current market demand for smart building solutions in Romania?
— What factors influence the decision–making process for clients considering smart building investments?
— What opportunities and challenges do you anticipate for the future growth of the smart building industry in Romania?

Q7) Collaboration and knowledge sharing:

— How do you collaborate with other stakeholders (architects, contractors, technology providers, etc.) to deliver successful smart building projects?
— Are there any industry networks or platforms you engage with to stay updated on the latest smart building developments?
— What initiatives do you support for knowledge sharing and capacity building within the civil engineering community regarding smart buildings?

The majority of participants in the study possessed a background in civil engineering, comprising 80% of the sample. Among the participants, 90% hold a diploma, while 10% have advanced degrees such as master's or PhDs. Notably, 60% of the participants have less than eight years of experience in the field, indicating a significant proportion of relatively early–career professionals.

Furthermore, 30% of participants have less than 15 years of experience, while 10% have less than 35 years of experience, suggesting a diverse range of expertise levels within the sample. Data analysis was conducted using SPSS Software version 22.0, enabling thorough examination and interpretation of the collected data.

Additionally, the rigor and validity of the semi–structured interviews were ensured through a meticulous assessment of the credibility of the obtained results. This process involved verifying the consistency and coherence of participants' responses, thereby enhancing the reliability of the qualitative findings.

RESULTS

Between May 1st and June 30th, 2024, a total of 50 semi–structured interviews were conducted as part of the research study. Importantly, all interviews were deemed valid, indicating a high level of quality and reliability in the data collection process.

This comprehensive approach ensured that a diverse range of perspectives and insights were captured from participants within the civil

engineering sector, contributing to the richness and depth of the study's findings.

Question Q1, based on the general understanding, and revealed that participants demonstrated varying levels of understanding of the subjects discussed. Specifically:

- 40% of participants indicated a very high level of understanding;
- 30% of participants expressed a high level of understanding;
- 26% of participants stated they had an adequate understanding; and
- 4% of participants admitted to having a limited understanding.

Moreover, the overall average certainty level among respondents was calculated to be 90% on a scale from 0 to 100. This indicates a relatively high level of certainty among the participants regarding the subjects discussed during the interviews. Such high certainty levels suggest a robust comprehension and confidence in the knowledge shared by the respondents, thereby enhancing the reliability of the study's findings.

The responses to question Q2 about the implementation and integration of smart building components revealed the following levels of knowledge among participants:

- 46% of participants indicated a very high level of understanding;
- 26% of participants expressed a high level of understanding;
- 22% of participants stated they had an adequate understanding; and
- 6% of participants admitted to having a limited understanding.

These findings suggest that a significant proportion of participants possess a solid grasp of this knowledge. However, there are still some participants who have insufficient knowledge in this regard. Overall, these insights contribute to a nuanced understanding of the level of awareness and comprehension among industry professionals regarding the implementation and integration of smart building technologies.

The responses to question Q3, focusing on technology and innovation revealed the following levels of knowledge among participants:

- 52% of participants indicated a very high level of understanding;
- 24% of participants expressed a high level of understanding;
- 20% of participants stated they had an adequate understanding; and
- 4% of participants admitted to having a limited understanding.

These findings indicate a notable level of awareness among participants regarding technological advancements and innovative solutions. The majority of respondents exhibit a solid grasp of this information, with only a small percentage feeling less confident in their knowledge. Overall, these insights contribute to understanding the degree of familiarity and comprehension among industry professionals regarding technology and innovation in the context of smart building implementation.

For question Q4, which focused on regulations and standards, the survey recorded the following responses from participants regarding their level of understanding:

- 48% of participants indicated a very high level of understanding;
- 32% of participants expressed a high level of understanding;
- 16% of participants stated they had an adequate understanding;
- 4% of participants admitted to having a limited understanding.

These results suggest that a significant majority of participants possess a strong understanding of regulations and standards relevant to the smart building industry. However, there is still a portion of respondents who feel they have insufficient knowledge in this area. Overall, these findings highlight the importance of adhering to regulatory requirements and industry standards in the implementation and operation of smart building technologies.

For question Q5, which delved into operational efficiency and maintenance in smart buildings, the survey yielded the following responses regarding participants' level of understanding:

- 44% of participants indicated a very high level of understanding;
- 36% of participants expressed a high level of understanding;
- 18% of participants stated they had an adequate understanding;
- 2% of participants admitted to having a limited understanding.

These results indicate a strong overall comprehension among participants regarding operational efficiency and maintenance in smart buildings. The majority of respondents demonstrate a solid grasp of these concepts, with only a small percentage feeling less confident in their understanding. This suggests a promising level of expertise among industry

professionals in optimizing operational performance and maintenance practices within smart building environments.

For question Q6, which explored market dynamics and the future outlook in smart buildings, the survey revealed the following distribution of responses regarding participants' level of understanding:

- 42% of participants indicated a very high level of understanding;
- 28% of participants expressed a high level of understanding;
- 26% of participants stated they had an adequate understanding;
- 4% of participants admitted to having a limited understanding.

These findings suggest that a majority of participants possess a strong understanding of market dynamics and future trends in the realm of smart buildings. Their high level of comprehension indicates a keen awareness of the evolving landscape and potential opportunities within the industry. However, there is still a small portion of respondents who feel they have room for improvement in their understanding of these aspects. Overall, these insights provide valuable context for decision–making and strategic planning within the smart building sector.

For question Q7, which focused on collaboration and knowledge sharing in smart buildings, the survey results indicate the following distribution of responses regarding participants' level of understanding:

- 54% of participants indicated a very high level of understanding;
- 26% of participants expressed a high level of understanding;
- 16% of participants stated they had an adequate understanding;
- 4% of participants admitted to having a limited understanding.

These findings highlight a strong overall comprehension among participants regarding collaboration and knowledge sharing within the smart building domain.

The majority of respondents demonstrate a robust understanding of these aspects, indicating a culture of collaboration and information exchange within the industry. However, there is still a small percentage of participants who feel they have room for improvement in their understanding of these dynamics. Overall, these insights underscore the importance of fostering collaboration and knowledge–sharing initiatives to drive innovation and progress in the smart building sector.

CONCLUSIONS

An extensive review of the literature concerning the integration of the Internet of Things (IoT) and Big Data Analytics in the advancement of smart buildings within the Romanian civil engineering context can offer invaluable insights into the prevailing research landscape, emerging trends, existing challenges, and prospective solutions within this domain.

Such a thorough examination of existing scholarly works holds the potential to illuminate the current status quo, identify patterns in technological adoption, pinpoint areas of concern, and propose innovative strategies to address them. Moreover, the exhaustive analysis of IoT's and Big Data Analytics roles in Romanian civil engineering enriches the collective knowledge base and provides practical insights for a diverse array of stakeholders, including businesses, researchers, policymakers, and more.

This study holds significant potential to shape decision–making processes, foster industry growth, and catalyze positive advancements in the Romanian IoT and Big Data Analytics landscape.

These insights hold significant implications for various stakeholders, as outlined below:

- Enhancing understanding and perception (by revealing how these technologies are perceived and utilized, the study facilitates the identification of both opportunities and challenges in their implementation);
- Recognizing barriers and risks (through highlighting associated barriers and risks, the study furnishes crucial information necessary for crafting strategies aimed at overcoming challenges and mitigating potential risks);
- Industry and supports services emphasis (targeting specific sectors refines the focus, rendering findings more pertinent and actionable for businesses operating within these fields);
- Providing insights for development (the study offers valuable guidance for policymakers, industry stakeholders, and academia);
- Bridging the business–academia divide (addressing real–world challenges serves to bridge the gap between academia and businesses, refining educational curricula and fostering collaborative efforts);
- Guiding policy and strategy (study findings can inform the formulation of policies that encourage innovation, infrastructure

enhancement, and the establishment of actual regulatory frameworks);
- Stimulating innovation (insight into the current landscape can ignite inspiration for innovations, new product offerings, and service developments aimed at addressing identified needs);
- Facilitating collaboration (serving as a catalyst for collaboration, the study encourages stakeholders to pool resources, share knowledge, and collectively drive the development of smart buildings solutions in Romania).

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WEIGHT OPTIMIZATION OF A SIMPLY SUPPORTED I-SECTION STEEL BEAM UNDER DEFLECTION CONSTRAINT

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Abstract: The scope of this research was to develop and study an optimization model used to minimize the weight of a simply supported I-section steel beam. The major criterion of this optimization model is the behavior of the structure under deflection as defined by BS 5950: Part1. The weight optimization is achieved by taking the geometric dimensions of the beam's cross-section as design variables. Due to the necessary idealization of the structure, unrealistic outputs had to be avoided by taking real life dimensions of UB steel sections as boundary geometric constraints. Results were derived from a sample case study and the observation of weight optimization with respect to parameters such as moment of inertia of steel sections and the span of the beam. Whilst the model produced increasing values of weight and optimized weights with respect to increasing spans, consistent values of moment of inertia was observed for optimized sections when weight optimization was performed.

Keywords: BS5950: Part 1, deflection, I-section steel beam, UB steel sections, weight optimization

INTRODUCTION

Compared to other building materials such as concrete, timber, masonry or earthworks, steel is a relatively new comer in structural construction. However, given the continuous spread and usage of industrial methods, it is a ubiquitous structural material.

The mass production of structural steel encourages the use of standard members for different structural elements (beams, columns, channels, etc.). The I-section beam focused on in this research is an example of such members. Even though the weight of an I-section steel beam is not a major criterion in the design of steel structures, its span and cross-section dimensions influence its behaviour in deflection under applied loads. However, these geometric dimensions of the structure directly determine its weight.

The optimization of steel beam design is confronted with the challenge of balancing the structural requirements, such as strength and deflection limits, with the imperative to minimize material usage and, consequently, the environmental and economic impact of construction projects. The weight optimization of steel beams is critical in this context as it directly influences the overall cost, resource consumption, and carbon footprint of a structure. However, this endeavor is complex due to the interplay of various design parameters and constraints, including safety standards and deflection limitations.

This thesis proposes to address the aforementioned challenge by developing a systematic approach for optimizing the weight of simply supported I-section steel beams while ensuring compliance with deflection constraints outlined in BS5950 Part 1. To achieve this, the study employed advanced computational methods, structural analysis techniques, and optimization algorithms to iteratively refine the beam's geometry and material distribution.

The design code defined by the research was BS 5950: Part 1. The researched literature for this was Frixos and Alan (2002). It showed the assumptions, design parameters and constraints to be made by the designer when designing the beam under deflection.

Steven and Raymond (2015) was consulted for this project. This work thoroughly discusses various optimization processes, why and when they are to be used. Here, the optimization problem of optimizing a constrained system with non-linear constraints was shown to require non-linear programming (NLP) for its solution. A list of optimization algorithms was also listed and discussed including: the simplex method, generalized reduced gradient (GRG) search method, genetic algorithms, simulated annealing and Tabu search.

Korkmaz and El-Gafy (2018) discusses the structural optimization of steel structures in the case of beam to column connections. This was done using Nonlinear Static Pushover Analysis. Despite the difference in methods used compared to this research, it demonstrated weight reduction under design constraints with each stage of analysis.

Paolo *et al.,* (2016) discusses the weight optimization of steel frames and trusses. However, genetic algorithms were used. The research included root radius in geometric parameters, resulting in a 15% weight reduction and integrating Finite Element Method simulations with a genetic algorithm.

Erkan and Aybike (2019) investigate the use of a hunting search algorithm to conduct weight optimization on steel frames. The commercial computer-aided design software ABAQUS is then used to create finite element models of each optimum frame for nonlinear analysis under loading. The study demonstrates that cellular beams can be used effectively in the design of steel frames to provide serviceability and strength while meeting design constraints such as maximum stress and buckling capacity.

Sharafi *et al*. (2014) investigated a method for optimizing the shape and size of steel sections using graph theory and the ACO algorithm. They conducted a multi-objective analysis with the goal of maximizing mass and strength. Because graph algorithms are good at finding the shortest pathways solution, the used graph theory approach was particularly suitable for optimum form analysis. In fact, because the thickness of the beam cross-section is uniform and constant, mass minimization simplifies the issue to section length minimization.

Searching for the minimum weight design has gained popularity over the years (Erdal , 2011; Hasancxebi and Carbas, 2014; Korouzhdeh and Eskandari-Naddaf, 2019). This search aims to detect the optimum geometry or the optimum topology and/or optimum cross-sectional dimensions for the members of a structure. To perform this, using structural optimization, a number of tools have been provided for structural designers (Carbas, 2016; Gholizadeh and Milany, 2018; Lagaros and Fragiadakis, 2007). One group of these tools, which may be categorized as traditional techniques, often faces difficulties in solving practical design optimization problems.

Kociecki and Adeli (2013) proposed a two-phase genetic algorithm for size optimization of free-form steel space-frame roof structures. They considered wind, snow and seismic loadings in linear structural simulations. The converge conditions allowed no more than 5% of overstressed beams. The achieved results provide a weight reduction of 12% using an automated design process.

Türker *et al*. studied the dynamic behavior of a two-story steel frame structure using simulations based on FEM analysis. They investigated the modal testing with and without braces. One of their remarks was that brace elements cause an increase in the natural frequencies because of the increased stiffening of the structures.

Compared to the aforementioned research works, this project is focused exclusively on a single steel member under the influence of deflection. The direct effect of certain beam properties that are geometric in nature such as length (span) and moment of inertia which were studied in this project have not been investigated to describe how they can influence the weight optimization of steel members (beam). The chosen scope is justified by the practical relevance of such beams in various structural applications, their susceptibility to weight reduction, and the critical importance of deflection control in real-world engineering projects.

The development of a computational framework for optimizing the weight of simply supported I-section steel beams was the primary objective of the research. Crucial to this was the incorporation of BS5950 Part 1 deflection constraints into the optimization process.

This research endeavors to contribute to the advancement of sustainable and cost-effective structural design practices while ensuring adherence to stringent safety and performance standards as mandated by BS5950 Part 1. Through the pursuit of these objectives, this research aims to provide valuable insights for engineers, designers, and researchers engaged in the optimization of steel structures.

MATERIALS AND METHODS

Materials

BS 5950: Part 1 is the design code for structural steel design. In this research, it was used in the development of the optimization model, specifically in the derivation of the deflection constraints and boundaries for the geometric constraints used. A personal computer with an Intel® CoreTM i3-6100U CPU @ 2.30 GHz, Windows 10 Home operating system, and 8GB RAM was used to run Microsoft Excel and execute the optimization process. An Excel spreadsheet was used to set up the model and the optimization process was executed using Excel's Solver Tool.

Optimization Method

Generalized reduced gradient (GRG) was the optimization algorithm used to carry out the

weight optimization. The model in this research consisted of an objective function developed for the weight optimization, which was a non-linear equation; with deflection constraints derived from BS 5950: Part 1. The generalized reduced gradient method is a direct method available in the Solver add-in in Microsoft Excel. The optimization problem was a non-linear constrained optimization problem, which the generalized reduced gradient algorithm can resolve.

Formulation of the Optimization Model

The model created describes a mathematical relationship between the weight of the beam and the corresponding geometric and material properties of the beam, required to derive its weight. This derived weight was then optimized while under constraints for both its deflection and geometry (size) using BS 5950: Part 1 as the design guide.

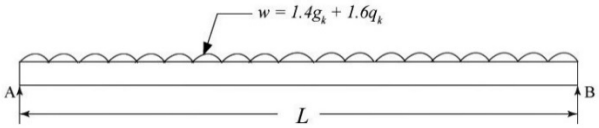

Figure 1: Loading condition and idealized structure of the model with factored loads according to BS 5950: Part 1.

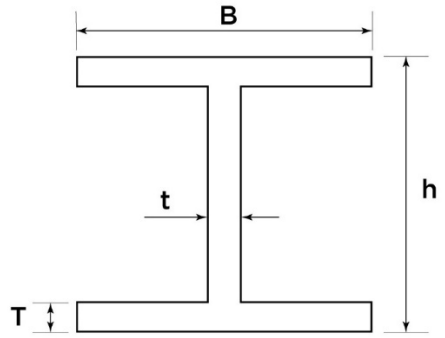

Figure 2: Cross-section of the beam with its geometric parameters used in the model.

Development of the Objective Function

The model optimizes the weight of a steel beam with a cross-section shown in Figure 2, which is a simply supported beam as shown in Figure 1. The weight of the beam is a function of the density of the steel and the beam's volume. The beam's volume is a result of the area of the beam's cross-section multiplied by its span.

Mathematically, the objective function is represented as:

$$\text{weight of beam} = \text{density of steel} \times \text{volume of beam} \quad (1)$$

$$M = \rho \times V \quad (2)$$

$$\text{Volume}, V = [2BT + t(h - 2T)] \times L \quad (3)$$

The objective function rewritten in full as:

$$M = \rho \times [2BT + t(h - 2T)] \times L \quad (4)$$

where:

M = Weight of the steel beam in kg.
ρ = Density of steel in kg/m^3.
L = Span of the beam in m.
T = Thickness of the beam's flange in mm.
t = Thickness of the beam's web in mm.
B = Width of the beam in mm.
h = Depth of the beam in mm.

Input Parameters

From equation 4, the weight function required certain inputs. They included both the terms defined above, as well as additional terms, which were used to compute the constraints.

The parameters for the geometric properties of the beam, as shown in Figure 1 and 2:

— Span of the beam (L).
— Width of the beam (B).
— Depth of the beam (h).
— Thickness of the beam's web (t).
— Thickness of the beam's flange (T).

All the input parameters used in the model are summarized in Table 1.

Table 1: Input parameters for the model

Parameter	Symbol	Unit
Span of the beam	L	m
Width of the beam	B	mm
Depth of the beam	h	mm
Thickness of the flange	T	mm
Thickness of the web	t	mm
Imposed load	q_k	kN/m
Dead load	g_k	kN/m
Steel density	ρ	Kg/m^3
Modulus of elasticity of steel	E	N/mm^2

Given that the nature of the research, the design constraints are for deflection. The magnitude of loads on the beam and beam structure (simply supported, with uniformly distributed load), were taken into account. The related inputs are:

— Imposed Load (q_k): These are all the other loads except that of the structure, fixtures and immovable parts loaded on the structure. It is factored according to BS 5950 by a partial factor of safety of 1.6.
— Dead Load (g_k): This is the weight of the structure itself and the weight of all loads permanently on it. It is factored according to BS 5950 by a partial factor of safety of 1.4. In this model, the derived weight from the objective function is added to the value directly inputted for the dead load when calculating the total load.

Finally, the material properties of the steel I-beam were also used to derive deflection constraints as demanded by BS-5950: Part 1. These included:

— Steel Density (ρ): This is the mass per unit volume of structural steel. From BS-5950, structural steel has a density of 7850kg/m^3.
— Modulus of Elasticity of Steel (E): This is also known as Young's Modulus, and is the ratio of stress to strain of a given material. Its value for steel is taken as 205000 N/mm^2.

Constraints

Behavioural and geometric constraints were developed using the BS 5950: Part 1 and the British Steel's table for Universal Beam (UB) section properties respectively.
Behavioural constraints were limited to deflections. To ensure that this constraint is fulfilled, the maximum possible deflection that will occur due to loading (δ_{max}) must not exceed the recommended maximum deflection permitted by BS 5950: Part 1. This allowable defection ($\delta_{allowed}$) is dependent on the span of the beam, while the maximum deflection (δ_{max}) is dependent on the imposed load, span, moment of inertia and the modulus of elasticity of the beam. Mathematically, the behavioural constraint in the model is:

$$\delta_{max} \leq \delta_{allowed} \quad (5)$$

where:

$$\delta_{max} = \frac{5WL^3}{384EI} \quad (6)$$

Where the terms W and I which are for the imposed load and moment of inertia (i.e second moment of area about a horizontal axis midway through the height of the beam.) are derived from:

$$W = q_k \times L \quad (7)$$

$$I = \frac{[Bh^3-(B-t)(h-2T)^3]}{12} \quad (8)$$

and

$$\delta_{allowed} = \frac{L}{360} \quad (9)$$

The geometric constraints were based on the maximum and minimum allowable steel sections from the British Steel's table for Universal Beam (UB) section properties. The minimum steel section had a designation 127 ×76×13 UB, while the maximum had a designation of 914×419×388 UB. The corresponding section properties of each both formed the lower and upper bounds of the set of geometric constraints. They are stated below:

$$127.0 \leq h \leq 921.0 \quad (10)$$
$$76.0 \leq B \leq 420.5 \quad (11)$$
$$4 \leq t \leq 21.4 \quad (12)$$
$$7.6 \leq T \leq 36.6 \quad (13)$$

All the values for the geometric constraints stated above are in mm.

Optimization Model and Required Outputs

Using the previously specified equations, the model was summarized as:
Minimize

$$M = \rho \times [2BT + t(h - 2T)] \times L \quad (14)$$

Subject to

$$\delta_{max} \leq \delta_{allowed} \quad (15)$$
$$127.0 \leq h \leq 921.0 \quad (16)$$
$$76.0 \leq B \leq 420.5 \quad (17)$$
$$4 \leq t \leq 21.4 \quad (18)$$
$$7.6 \leq T \leq 36.6 \quad (19)$$

where:

$$\delta_{max} = \frac{5WL}{384EI} \quad (20)$$

$$\delta_{allowed} = \frac{L}{360} \quad (21)$$

To find $X = [X_1X_2X_3X_4]$ which minimizes the objective function while satisfying the constraints stated above.
Where:

$$h = X_1 \quad (22)$$
$$B = X_2 \quad (23)$$
$$t = X_3 \quad (24)$$
$$T = X_4 \quad (25)$$

The matrix X, consists of the design variables. Design variables are inputs into the model that are present in the objective function that were adjusted in order to achieve weight optimization. The outputs of the model included both the result of the optimization and the design variables.

Table 2: Outputs of the optimization model.

Parameter	Symbol	Unit
Width of the beam	B	mm
Depth of the beam	h	mm
Thickness of the flange	T	mm
Thickness of the web	t	mm
Weight of the beam	M	Kg

Model Optimization

The weight optimization of the modeled steel I-beam was performed in Microsoft Excel using the Solver add-in after the mathematical description of the model was replicated using a spreadsheet.

Development of Excel Spreadsheet

An Excel spreadsheet was used to represent the model by replicating the mathematical formulas of each of the necessary parameters in relevant cells as shown in Figure 3.
Once the spreadsheet was created, the Solver button was selected from the Data tab on the Excel interface. The Solver dialogue box displayed was then filled with pertinent data from the spreadsheet. The solving method selected in the Solver dialogue box was the

Generalized Reduced Gradient Non-linear algorithm method.

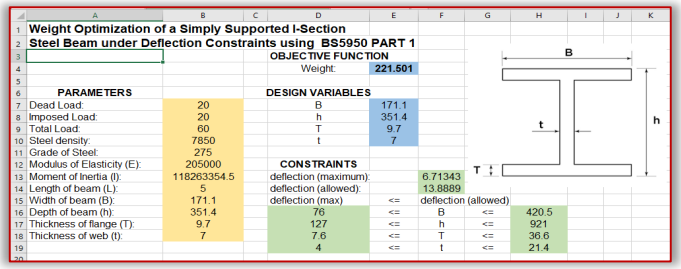

Figure 3: Excel spreadsheet set up to evaluate the weight optimization of a simply supported I-section steel beam subject to deflection constraints.

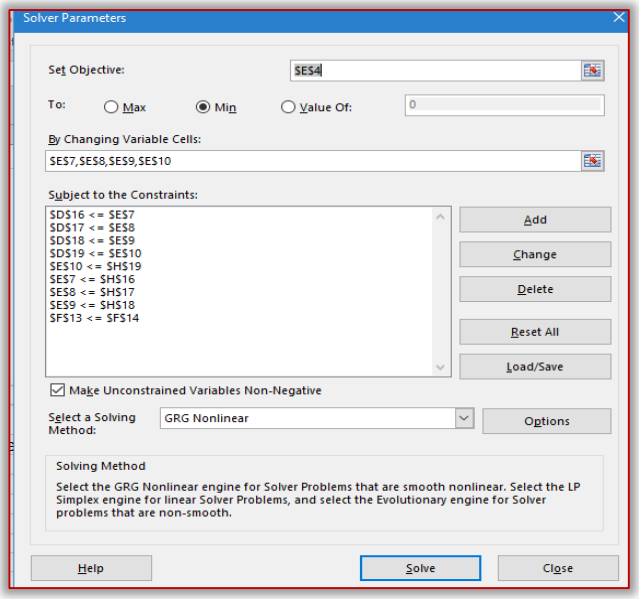

Figure 4: Solver dialogue box with relevant cells filled with information from the spreadsheet.

Derivation of Results

After using the Solver dialogue box to solve the optimization model, the values in the cells containing the design variables were changed due to the success of the operation. This also led to a corresponding change in the weight of the beam. The previous values of both the objective function and design variables are recorded, as well as the corresponding values after the optimization process has been completed.

RESULTS AND DISCUSSION

An optimization study was done on a select steel I-section beam with preassigned conditions and parameters. The UB steel chosen had a designated serial size of 457 × 191 × 89. The input parameters used in the case study are shown in the table below.

In addition to those, there were initial values chosen for each design variable before the weight optimization occurred. These are presented in Table 4.

The results of the subsequent optimization are shown in Table 4. In addition, there was a comparison of the values chosen for each design variable and objective function (weight) with those values presented by the model as it completes its weight optimization process.

Table 3: Input parameters for the case study optimization.

Parameter	Value
Dead Load	30 kN/m
Imposed Load	30 kN/m
Total Load	90 kN/m
Steel density	7850 kg/m^3
Grade of Steel	275 N/mm^2
Modulus of Elasticity (E)	205000 N/mm^2
Moment of Inertia (I)	406147473.3 mm^4
Length of beam (L)	8 m

The comparison, represented by Gain (%) and was calculated using this equation:

$$\text{Gain (\%)} = \frac{\text{initial value} - \text{optimal value}}{\text{initial value}} \times 100\% \quad (25)$$

The same formula was used to derive weight reduction (%).

Table 4: Optimization of the design study, showing initial and optimal values.

Design Variables	Initial Values	Optimal Solution	Gain (%)
B	191.9	76	60.396
h	463.4	808.088	-74.382
T	17.7	7.6	57.062
t	10.5	4	61.904
Weight (kg)	708.4	271.2	61.716

As seen in the above table, all the variables had shown a considerable decrease from their initial values, with the exception of the height of the beam, h which showed a gain of -74.382%.

A weight reduction from 708.4 kg to 271.2 kg was observed from the optimization model study, which is equivalent to a 61.716 % reduction.

Weight Optimization under Varying Span Length

Weight optimization was also executed at various span lengths of the beam. Its span was incrementally increased from 1 to 10 meters and weight optimization was performed at each step. The results from the optimization are shown below.

Table 5: Weight optimization results with varying span lengths.

Span, L (m)	Weight (kg)	Optimized Weight (kg)	Weight Reduction (%)
1	88.605	12.579	85.803
2	177.210	28.010	84.194
3	265.815	53.449	79.892
4	354.420	87.716	75.251
5	443.025	131.100	70.408
6	531.630	183.739	65.439
7	620.235	245.712	60.384
8	708.840	329.194	53.559
9	797.445	454.378	43.021
10	886.050	621.472	29.860

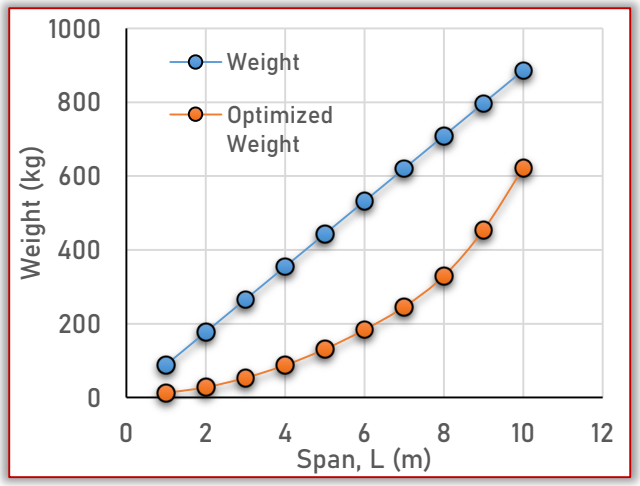

Figure 5: Graph of Span (m) against Weight (kg).

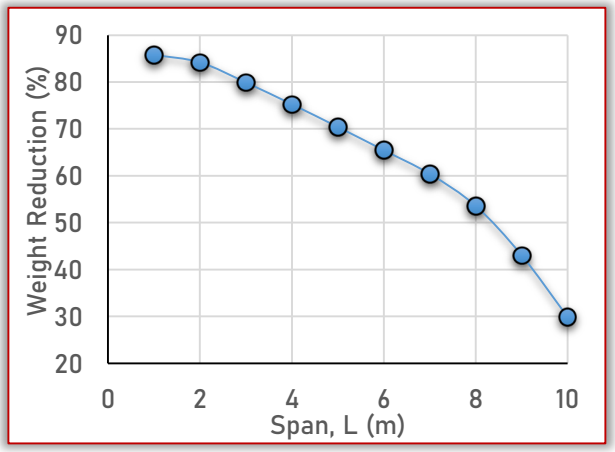

Figure 6: Graph of Span (m) against Weight Reduction (%).

There is a steady increase in the values of the beams weight as the span increases in length. This matching increase also occurs for the optimized weight even though its values are lower than those of the original weights.

However, given the nature of the graph for the optimized weights, and the steadily decreasing values of the weight reduction, the optimized weight at a given span would match the values of the original weight.

The weight of the beam showed an increase from 88.605 kg to 886.05 kg as the span of the beam was increased from 1.0 to 10.0 meters. The corresponding change from the optimized weight was from 12.579 kg to 621.472 kg, which resulted in a decrease of the weight reductions from 88.803% to 29.86%.

Weight optimization with varying steel sections

The model executes weight optimization on a simply supported I-section steel beam, where the steel beams according to BS 5950: Part 1 are of different designated sections. Each of these steel beams have different geometric properties (i.e values for h, B, t and T) and correspondingly have different values of moment of inertia (I) and weight.

Table 6: Steel sections with varying geometric properties, moment of inertias and weights.

Section	h (mm)	B (mm)	t (mm)	T (mm)	Moment of Inertia (mm^4)	Weight (kg)
127 x 76 x 13	127	76	4	7.6	4588602.14	62.8942
254 x 146 x 37	256	146.4	6.3	10.9	54707487.3	183.179
356 x 171 x 45	351.4	171.1	7	9.7	118263355	221.501
457 x 152 x 60	454.6	152.9	8.1	13.3	250996307	295.707
533 x 210 x 122	544.5	211.9	12.7	21.3	751901483	604.492
686 x 254 x 125	677.9	253	11.7	16.2	1159695535	618.167
762 x 267 x 147	754	265.2	12.8	17.5	1655425543	725.544
838 x 292 x 226	850.9	293.8	16.1	26.8	3354667170	1121.930
914 x 419 x 388	921	420.5	21.4	36.6	7109008167	1920.248

Weight optimization was performed on the above sections with respect to the moment of inertia and weights respectively.

Weight Optimization with Varying Moment of Inertias for Steel Sections

Weight optimization was performed on the steel sections with respect to the moment of inertia and the moment of inertia of the optimized section was observed and recorded.

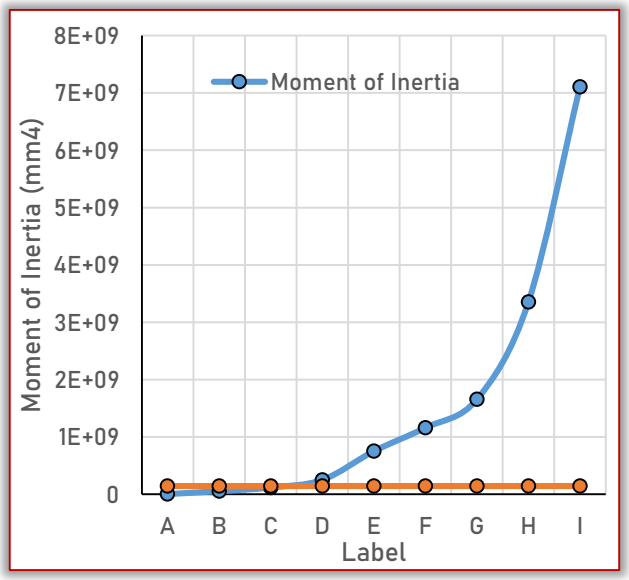

Figure 7: Graph of moment of inertia of different sections underweight optimization.

Table 7: Weight optimization on designated steel sections with respect to moment of inertia.

Section	Label	Moment of Inertia (mm^4)	Optimal Moment of Inertia (mm^4)
127 x 76 x 13	A	4588602.141	142915528.5
254 x 146 x 37	B	54707487.29	142911590.6
356 x 171 x 45	C	118263354.5	142911604.6
457 x 152 x 60	D	250996307	142911579.7
533 x 210 x 122	E	751901482.9	142911584.6
686 x 254 x 125	F	1159695535	142911434.4
762 x 267 x 147	G	1655425543	142911585
838 x 292 x 226	H	3354667170	142911586
914 x 419 x 388	I	7109008167	142911585.7

As the moment of inertial increases for each respective section, the moment of inertia for the optimized section generally decreases by relatively small amounts. This is seen from Figure 7 and Table 7, where the optimal moment of inertia appears to have a singular value with very minute variations regardless of the values of the original moment of inertia.

Weight Optimization with Varying Weights for Steel Sections

Weight optimization was performed on the steel sections with respect to the weight and the weight of the optimized section was observed and recorded.

Table 8: Weight optimization on designated steel sections.

Section	Label	Weight (kg)	Optimal Weight (kg)	Weight Reduction (%)
127 x 76 x 13	A	62.894	131.100	-108.445
254 x 146 x 37	B	183.179	131.099	28.431
356 x 171 x 45	C	221.501	131.099	40.813
457 x 152 x 60	D	295.707	131.099	55.666
533 x 210 x 122	E	604.491	131.099	78.312
686 x 254 x 125	F	618.169	131.099	78.792
762 x 267 x 147	G	725.544	131.099	81.931
838 x 292 x 226	H	1121.930	131.099	88.315
914 x 419 x 388	I	1920.248	131.099	93.173

Similar to the weight optimization with respect to moment of inertia, the optimization study of the section weights results in the optimized weights similarly converging to a singular value with very minute deviations as seen in Table 8.

This value of the optimized weights is approximately 131.1 kg is maintained regardless of the variance of the original section weights. This leads to an initial weight reduction of approximately -108.445% which increases as the original weights increases to approximately 93.173% on the final section.

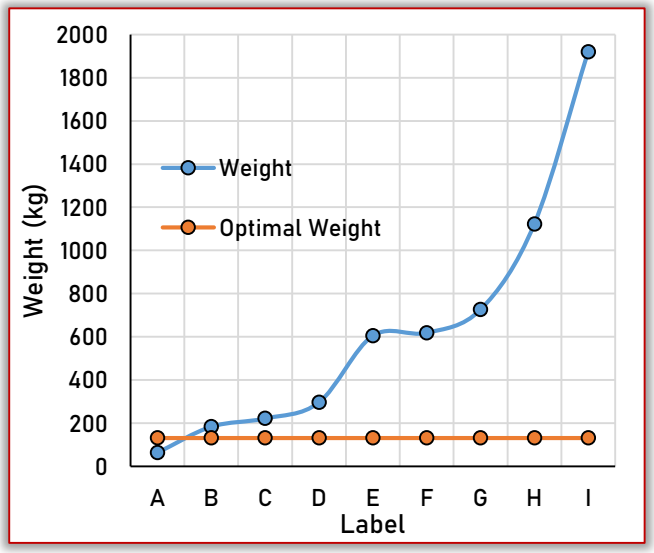

Figure 8: Graph of weight of different sections underweight optimization.

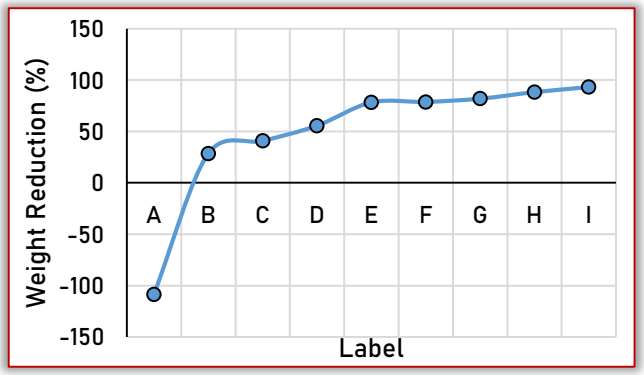

Figure 9: Graph of weight reduction of different sections under weight optimization.

CONCLUSION

The following conclusions can be made based on the results obtained from the study:

- An increase in the span length of the beam directly led to an increase in the original weight and also the optimized weight.
- The weight reduction (%) reduces as the span increased.
- Increase in a sections moment of inertia increases the weight of the beam. However, the optimized weight and moment of inertia show almost no variation from a single value.
- Weight reduction (%) increases with respect to the moment of inertia and the resulting weights of sections.

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TURBULENCE EFFECT FROM THE POINT OF VIEW OF NON–CLASSICAL THERMODYNAMICS

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Abstract: The Ranque vortex tube (effect Ranque) is a device by which cold gas can be generated using compressed gas. In this article, the process of gasses' thermal division in turbulent tubes is described on the basis of thermodynamic theory according to Newtonian time. Based on new approach, explaining the essence of the effect of the temperature separation of gas and procedure of the thermodynamic calculation. The separation of a gas steam delivered to a tube, through a tangential nozzle into streams with different stagnation temperatures, is a phenomenon that has not yet been fully investigated. As in this paper shown, the approach of thermodynamic calculation can be applied for the Ranque vortex tube and other separator (dividing) systems

Keywords: Non–local thermodynamic, Ranque effect, Vortex pipe

INTRODUCTION

The phenomenon of two gas streams separated without mechanical assistance was discovered by George J. Ranque in 1933 and the subject of a US Patent in 1934. The tube later became known as the Ranque vortex tube. Compressed gas, air, enters the device tangentially to create a vortex that travels through a generation chamber. The air is then reflected with a conical valve. The conical valve adjusts the balance of the amount of air that is allowed to escape and the amount that is forced back through the axis of the vortex. This balance is known as the cold fraction. The temperature drop is a function of the ambient temperature, pressure, cold fraction, and flow of compressed gas. Cold exit temperatures can reach as low as –40°C.

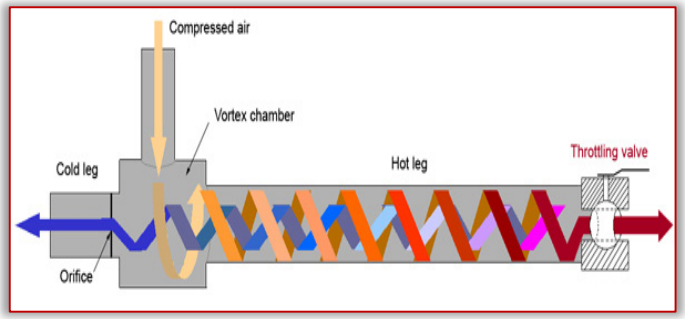

Figure1. Separation of a compressed gas into a hot stream and a cold stream

Turbulent Ranque effect is a typical macro–quantum phenomenon, which cannot be described by classical theory. About a century of unsuccessful experience in defining this phenomenon based on classical methods testifies to this. There are different explanations for the effect and there is debate on which explanation is best or correct. The explanation of this phenomenon has been the center of much research since its discovery. There is still no universally adopted theory that explains the effect of the vortex. The vortex tube is considered the result of several simultaneous phenomenon's.

Another new approach to solve this problem is using non–local version of thermodynamics, developed in the Moscow State University of Engineering Ecology [1]. The basic idea of non–local thermodynamics is to use quantum entropy, with every quantum defined as equal to Boltzman constant–k. This hypothesis will allow to apply thermodynamic energy –kT. Further, correlations of quantum mechanics are used. For brevity purposes, only the relation of energy–time is used here:

$$\Delta E \Delta t = \frac{h}{2} \quad (1)$$

Using $\Delta E = kT$ in the relation (1) allows establishing the minimum interval macroscopic processes that depend only on temperature:

$$\Delta t = \frac{h}{2kT} \quad (2)$$

In addition, radius r and volume V in the environment for time Δt is:

$$r = c\Delta t = \frac{ch}{2kT} \quad (3)$$

$$V = \frac{4}{3}\pi r^3 = \left(\frac{\pi}{6}\right)\left(\frac{ch}{kT}\right)^3 \quad (4)$$

For example, at $T = 293K$, by using relations (2), (3), (4) we will receive following results: $\Delta t = 1.3 * 10^{-14}s$, $r = 3.9 * 10^{-6}m$, $V = 2.5 * 10^{-16}m^3$

Volume V, calculated using the minimum sizes of $\Delta E, \Delta t, k$ on physical sense is the minimum macroscopic volume. The enclosed area by this volume is named macro cell in non–local version of thermodynamics. The macro cell can be considered as shortly living and special physical cluster, over the molecular level in hierarchy of macroscopic system. Characteristic of a macro cell as a physical self–reliant object is that, on the

one hand, it is the maximum microscopic volume and quantum mechanics laws apply to it, and on the other hand, is the minimum macroscopic volume, to which apply minimum classical definitions. Hereafter there is a possibility of simultaneous existence of Boltzman and Planck constants at macro level. For example, in the new approach it has been shown that the ensemble of particles in a macro cell act as a unit and their collective speed at time Δt is $v = (\frac{kT}{m})^{0.5}$. In other words, in non–local version of thermodynamics, balance is considered as dynamic resilient position and for its maintenance, function of certain forces is required which depend on temperature:

$$F_m = \mp \frac{m}{\Delta t}\sqrt{\frac{kT}{m}} \quad (5)$$

It was on this basis that Ranque effect was described thermodynamically [2].

CALCULATION

For this purpose, we will start with some macroscopic elements in hydrodynamics. In the way that the macroscopic elementary stream will have the maximum section of a macro cell, the connected surface stream will have a thickness of 2r, where r is macro cell radius. Obviously, macroscopic the elementary stream will have a radius of R with the maximum section of a macro cell.

Let the ensemble of such elementary streams have a macroscopic and connected surface stream of width b and volume $V = 2brR$, but the attached surface stream with N package will have such volume of $V\rho = 2brRN$.

The mass of surface package of stream is calculated from the following relation:

$$M = 2brRN\rho \quad (6)$$

Where ρ indicates density, and N indicates the number of elementary surface vortex.

In a vortex tube, the centrifugal force arising in a macroscopic vortex (6) operates with angular speed ω:

$$F = M\omega^2 R \quad (7)$$

Force F as an external force acts on macro cell of non–local version of thermodynamics in which operates resilient force (5). As a result, according to the non–local version of thermodynamics, the macro cell moves from one equilibrium to another dynamic equilibrium position, observing the equality of centrifugal force and resilient inertial forces in a macro cell. At resilient equilibrium state of this position, the other macro cell will have a new temperature according to the relation (5). Equating (5), (7) it results in:

$$M\omega^2 R = \frac{m}{\Delta t}\sqrt{\frac{kT}{m}}$$

Considering $m = V\rho$ and (6) we will have: $2br\omega^2 R^2 N\rho^{0.5} = \frac{V}{\Delta t}\sqrt{\frac{kT}{V}}$

As $V = \frac{4}{3}\pi r^3$, $\Delta t = \frac{h}{2kT}$, $r = \frac{ch}{2kT}$, it is possible to have the following ratio:

$$b\omega^2 R^2 N\rho^{0.5} = aT \quad (8)$$

here $a = \pi ck(\frac{2}{3}\pi ch)^{0.5} = 0.0337\ (m.j)^{3/2}/s.K$ (a collection of constants)

Thus, the right side of expression (8) only depends on temperature and some basic constants. Parameters in the left part depend on current vortex's radius R_i, and so we can write the following expression:

$$(\omega^2 bR^2 N\sqrt{\rho})_i = aT_i \quad (9)$$

Later expressions (8), (9) are the main equations for describing the regime and structural effect of parameters of Ranque vortex tube, which are obtained exclusively based on macro quantum parameters.

One can easily analyze hydrodynamic vortex attached to the tube's internal wall. For this purpose, we may use linear speed in tube's entrance of vortex tube's connector, which has been calculated on the basis of entrance section of connector tube's nozzle and specific efficiency $v = 2\pi R\omega$. Whence $\omega = \frac{v}{2\pi R}$ and finally, from relation (7) we will get:

$$v^2 bN\rho^{0.5} = a`T \quad (10)$$

here, $a` = 4\pi^2 a = 1.3304\frac{(mJ)^{\frac{3}{2}}}{sK}$, i.e. in the condition of applying optional linear speed, entrance stream of Ranque effect is determined by dependent package bN and density ρ.

Amount of selection of cold (hot) stream should be considered separately. Selection affects hydrodynamic stream. So we will consider the linear speed at tube's wall equal to $v_R = 2\pi R\omega_R$ and $v_i = 2\pi R_i\omega_i$. Dividing v_r on v_i we'll have:

$$v_i = v_R(\frac{R_i}{R})(\frac{\omega_i}{\omega_R}) \quad (11)$$

The ratio of first relation decreases as the radius of vortex decreases, but the second ratio may increase which results in the decrease or increase of external stream's temperature. This naturally influences selection of hot stream. Therefore, selection influence can lead to a minimum of external stream's temperature and a maximum of division efficiency. If we arrive at the conclusion that thermodynamic nature of all division processes is identical, optimum thermodynamic selection will have always an identical probability without any special

restrictions, i.e. the ratio of selections of cold and hot streams should be equal. These facts have been proved by examinations.

EXPERIMENTS

The analysis of industrial cyclone devices "NIIOGaz" type 15–D×1YP by calculating various entrance parameters according to the obtained mathematical model (10) showed that for a regime, which its temperature has not exceeded its boiling point, just 3–12 macroscopic elementary vortexes of "solid–state" character are needed. Initial data of the cyclones "NIIOGaz" type 15–D×1YP is represented in Table1. All calculation data on the cyclones "NIIOGaz" type 15–D×1YP are represented in Table 2.

Table 1. Initial data of the cyclones "NIIOGaz" type 15–D×1YP

D	300	400	500	600	1400
Q	1000	1800	2800	4100	22200
h*b	206×86	274×114	340×140	406×166	934×374
D_1	172	230	290	350	830

In the table: D= diameter, mm; Q= volume expense, m^3/h; $h * b$= the overall sizes of rectangular inlet duct, mm; D_1= the diameter of exhaust duct, mm.

Table 2. Calculation data on the cyclones "NIIOGaz" type 15–D×1YP

D(mm)	300	400	500	600	1400
$Q = m^3$	0,28	0,50	0,78	1,14	6,17
G_c(kg/s)	0,60	1,08	1,68	2,46	13,33
v_c(m/s)	15,68	16,01	16,34	16,90	17,68
N	12	9	7	6	3

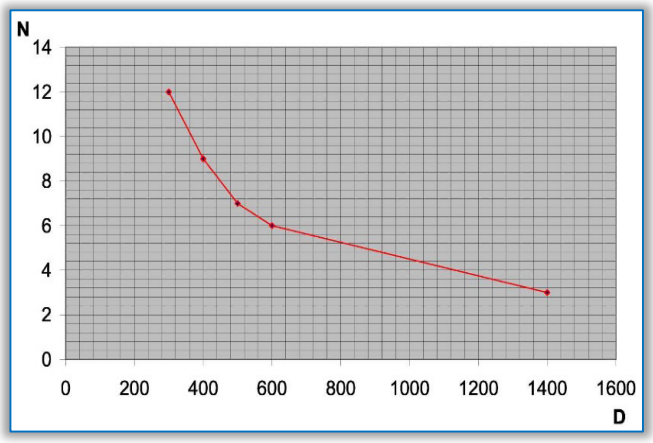

Figure.2. Changes of the number of macroscopic vortexes as compared to diameter of vortex tube for the (calculation) devices

This analysis shows that in order to maintain required effect without exceeding boiling point, we just need to have kept a thin wall layer in dependent vortex of solid object. Such a state regarding solid object in the region of vortex tube in the experimental work [3] has been considered based on high–speed filming. In this work, maximal temperature difference on the exits of the vortex tube was about 60–70 degrees at the drop of pressure.

The dependence of a change in the linear speed on the portion of flow (processing experimental data) is represented in table 3.

Table 3. The dependence of a change in the linear speed on the portion of flow (processing experimental data)

m	0,98	0,92	0,86	0,80	0,74	0,67	0,60	0,52
v	43,80	43,51	43,29	43,10	42,90	42,70	42,52	42,37
m	0,41	0,31	0,23	0,17	0,15	0,12		
v	42,39	42,53	42,72	43,01	43,14	43,51		

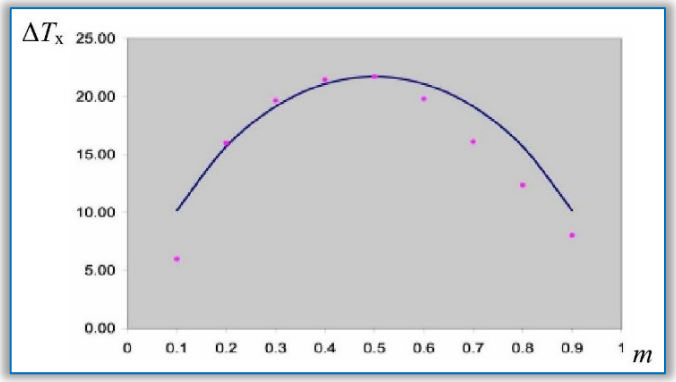

Figure3. Comparison of the computational data with experimental data Calculation —, Experiment •••• (T=293K, G=0,0032kg/s, P=168KPa)

Researches were done on a Ranque tube with separable box's diameter of D=18mm and length of $L = 125mm$. The experimental stand was equipped by the modern measurement and control set of equipments and automation equipments and advanced integral software programs.

Of experimental data, all regime parameters, which are used in the formula (10), except the number of macroscopic elementary dependent vortex, are clear in the package N. Their number was calculated 16 with general thickness of $2rN = 0.11mm$. For comparison it should be noted that in this experiment there are $\frac{h}{2r} = 513$ dependent elementary macroscopic layer in the opening of entrance tube.

RESULTS and DISCUSSIONS

During processing of experimental data with various ratios of products it has been noticed that multiplication of vbN in the formula (10) changes unnoticeably by change of selection of product in the selection region of $m = 0.5$. According to this feature, thermodynamic method of the analysis of the vortex equipment's was formulated, and following results were obtained accordingly:

1–On the basis of regime and structural parameters of vortex tube, the number of elementary macroscopic vortex for the regime of vortex tube N without exceeding of temperature from boiling point was calculated:

$$N = 4\pi^2 aT\rho^{\frac{3}{4}} bh^2/G^2$$

2–The analysis of the received result was carried out. There should be enough macroscopic vortexes so that the increase of vortex's width (b) when the stream enters the vortex tube, does not lead to decrease of wave to $N < 1$. On the opposite, macroscopic vortex will transform to a microscopic state, which is the state of non–formation of stream's cooling effect. To avoid this state, we may increase N against what we did at first and change the regime and structural parameters of device.

3–Recommended radius of selection of hot stream with theoretical justification in $m = 0.5$:

$$R_k = R - \left(\frac{1}{2}\right)h$$

4–We can estimate ideal of stream for macroscopic state by using information entropy of Shannon for two streams at the state of $m = 0.5$:

$$\frac{T_{in} - T_c}{T_{in}} = \frac{\Delta T_c}{T_{in}} = H$$
$$= -m \ln m - (1 - m)\ln(1 - m) = \ln 2 = 0.693$$

5– Real efficiency of cooling could be estimated. For an analyzed vortex tube this size equals to $\left(\frac{\Delta T_C}{T_{in}}\right) = 0.0741$. Hence, the coefficient of thermodynamic positive function will read: 0.0741/0.693= 0.107.

CONCLUSIONS

The separation of a gas steam delivered to a tube, through a tangential nozzle into streams with different stagnation temperatures, is a phenomenon that has not yet been fully investigated. As you see, the approach of thermodynamic calculation can be applied for the Ranque vortex tube and other separator (dividing) systems [5]. To analyze the mentioned method, experimental data of PhD thesis of doctorate student of Moscow State University of Engineering, M.A. Terekhov (2004), which was done under supervision of Professor O.A. Troshkin, were used [4].

Symbols

c – Velocity of light in vacuum, c =2.998*10^8m/s
F_m – Inertial force in a macro cell, N
ħ – Planck's constant, ħ = 1.055*10^{-34}J.s
k – Boltzma's constant, k = 1.381*10^{-23} J/K
m – Weight of a macro cell, kg
M – Molecular weight, kg/kmol
P – Pressure, N/m^2
R_i – Radius of a current whirlwind, m
r – Macro cell radius, m
T – Absolute temperature, K
Δt – The minimum macroscopical time scale, s
ρ – Density, kg/m^3
ω – Frequency (angular speed), 1/s
D – Diameter of a vortex tube, m
L – Length, m
m – Relative (dimensionless) share of cold stream
Q – The volume expense, m^3/s
υ – Linear speed, m/s
V – Whirlwind volume, m^3

Subscripts

c – Cooled stream

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