Nemzeti Tehetség Program

Scientific, Technical and Art Releases – 2021

Scientific, Technical and

Art Releases – 2021

Published by:
Óbuda University
Rejtő Sándor Faculty of Light Industry and Environmental Engineering
Institute of Media Technology and Light Industry

Supported by:
Integrált Tudományok Szakkollégiuma, Óbuda University
(College of Integrated Sciences)

Editor-in-Chief:
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Budapest, 2021

ISSN 2786-3638

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ENERGY YIELDS OF A SMALL SOLAR POWER PLANT

Lóránt SZABÓ

Abstract: *Research of renewable energies, including solar energy, is very popular nowadays. Solar energy is a powerful source of energy that can be applied to heat and electricity supply by photovoltaic panels (PV) and available everywhere on the Earth since the beginning of time. Solar irradiance at the Earth's atmosphere was determined. Solar energy is so-called green energy without any CO2 emissions. Solar radiation has two utilisations passive and active. We examined a 51 kW peak solar power plant with 200 pieces of polycrystalline silicon panels in Hungary. We calculated its efficiency, payback time, and the amount of carbon dioxide protected by the environment. These days PV panels are getting cheaper. Hungary is committed to ten times its solar power capacity (yield) by 2030.*

Keywords: *solar energy, photovoltaic panel, efficiency, payback time*

INTRODUCTION

The term is thrown around frequently in discussions on green living, oil dependency, and climate change. Renewable energy is a reliable energy source that includes (Figure 1): solar, wind, geothermal, hydropower, biomass, and tidal energy.

Aside from geothermal and tidal energies, renewable energy sources are replenished constantly by sunlight. Renewable energy generates negligible levels of carbon emissions.
The utilisation of solar energy means a sustainable solution to many urgent problems, e.g., solar energy is environmentally friendly since there are no emissions during use. There are two available options for the utilisation of solar energy:

- passive, and
- active utilisation.

The passive utilisation of solar energy is when the sunlight is converted into thermal energy without any additional equipment and devices (Figure 1). The ancient people already knew this method. Today, passive utilisation is carried out by placing buildings and designing their structure. The buildings should be oriented so that the rooms with the most significant heating needs face south, southeast, east, while the rooms with smaller heating needs insulate them. Layered wall structures have insulating and heat-storing properties as well. We can take advantage of solar radiation by using large glass surfaces. The best is if they are used in an integrated manner.

We are talking about active solar utilisation when we use a photovoltaic (PV) cell or a photothermal device (solar collector) which helps to utilise the terrestrial solar radiation (Figure 1). The solar panel system is suitable for covering the heating needs or hot water production [7]. The production of electricity can happen in two fundamentally different ways, with the help of using direct and indirect energy conversion. Solar radiation energy is converted directly into electrical energy during direct energy conversion. The tools for this are the various types of solar cells. In the case of indirect energy conversion, the first step is to convert the solar energy into heat energy by using some kind of solar collector and then produce electricity with the help of a thermal cycle. Such systems are called solar thermal power plants. The resources given in Hungary are favourable in terms of solar energy utilisation compared to many other European countries.

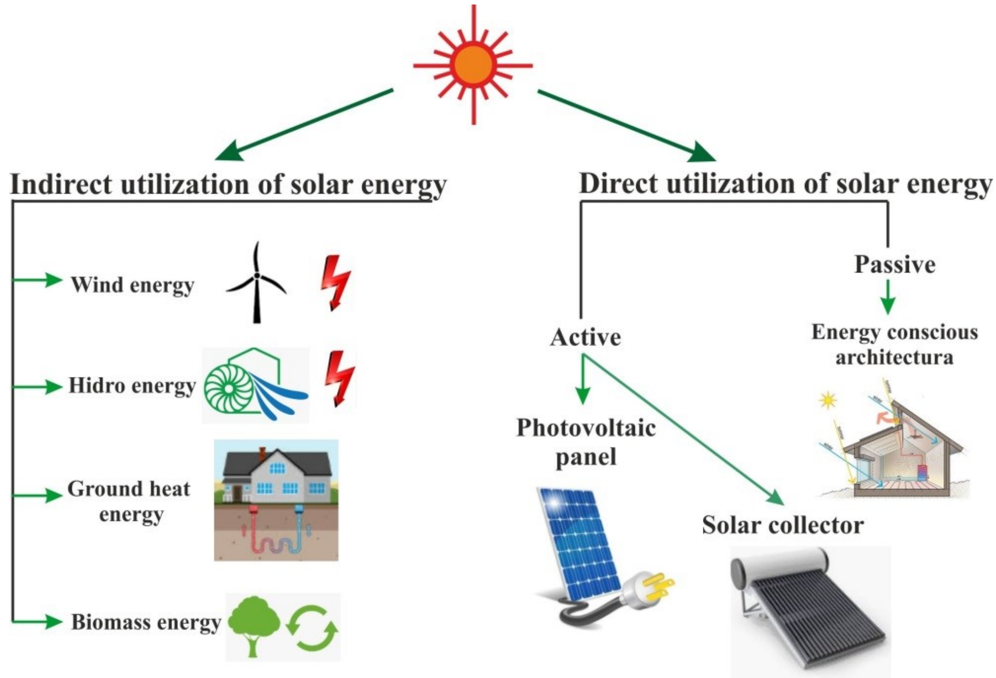

Figure 1: Application of solar energy

Buildings' immediate energy needs are due to heating (cooking) and/or cooling, depending on local climatic conditions and type of building. Thione world application of solar energy (photovoltaic – PV) has grown at a fantastic rate in the past few years (Fig. 2).

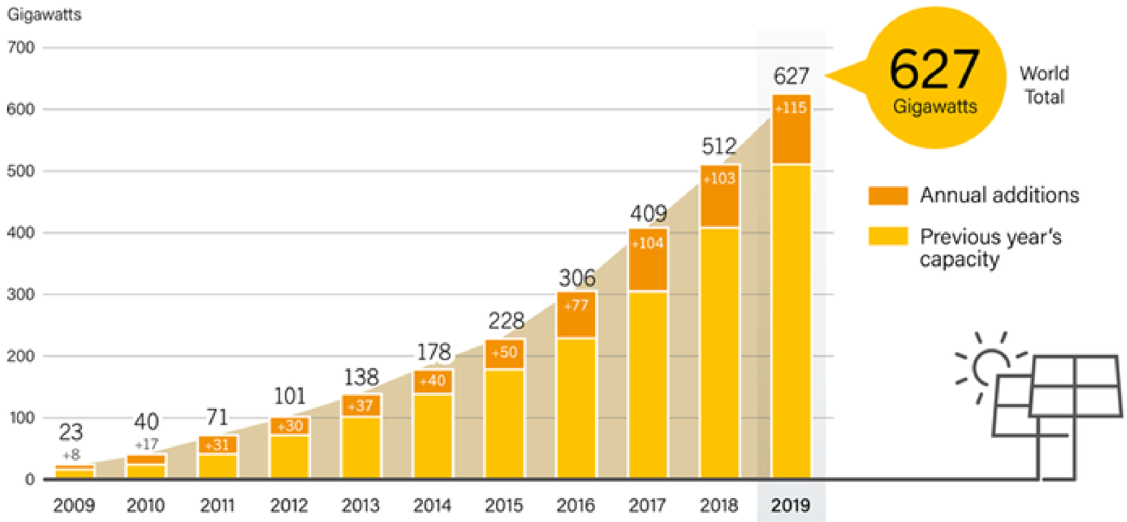

Figure 2: Solar PV yields since 2009 in the world

With new power records, the size of photovoltaic (PV) power stations has increased progressively over the last decade. World's largest PV power stations can be found in China (2400 MW_p), India (2700 MW_p), United Arab Emirates, and the United States

Solar power is a rapidly growing technology in Hungary, despite significantly lagging behind most European countries. (Table 1)

Table 1: List of the most significant PV power stations in Hungary [12]

Number	Name	Power [MWp]	Opened
1	Paks Solar Park	20.6	2019
2	Mátra Solar Power Park	20	2015, 2019
3	Felsőzsolca Solar Park	20	2018
4	Duna Solar Park	17.6	2018

THE ENERGY RELATIONS OF SOLAR THERMAL RADIATION

Hungary has **excellent** potential for solar energy, as **Hungary's number of sunny hours** is between 1,950-2,150 per year. In addition, the annual amount of incident solar radiation is 1200 kWh/m^2 (Figure 3). **Solar** energy can provide hot water and electricity by photovoltaic panels.

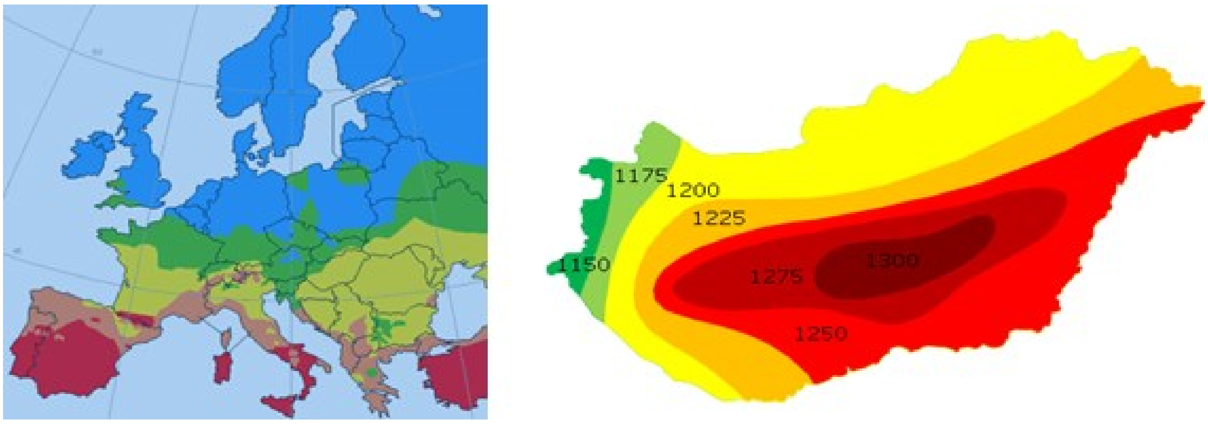

Figure 3: Global horizontal irradiation in Europe and Hungary in $kWh/m^2/year$

The Southern and central parts of Alföld (in Hungary) have the ideal location for solar energy usage. The mountainous western and northern regions are less good in this regard (Fig. 3).

The intensity of the solar electromagnetic radiation that reaches the upper layer of the Earth's atmosphere is about 1352 W/m^2. This value is also called solar constant (with medium Sun-Earth distance). The energy use of solar energy depends on spectral dispersion and the fluctuation of the intensity of the radiation. The usable radiation depends on the following other elements:

• the geographical location
• the changing of seasons and part of the day
• climate factors (weather and topography factors)
• the orientation of the solar panel and its tilt angle (in Hungary, with southern orientation 40° is the ideal angle)
• the temperature of the environment (changes in the temperature cause changes in the efficiency), and
• cleanliness of the solar cells.

One part of the radiation enters the atmosphere directly unweakened. In contrast, the other part of it spread on the particles in the atmosphere (dust, water vapour, pollutants) and on the clouds, without any definite direction, reaching the Earth's surface as diffuse radiation. (Fig. 4)

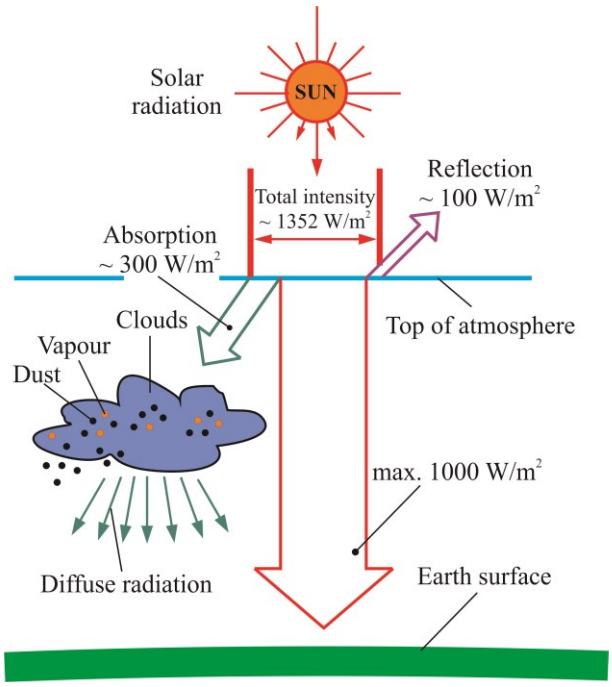

Figure 4: The conditions of solar radiation reaching the Earth's ground surface

A significant portion of the nearly 1000 W/m^2 power solar radiation that reaches the Earth's surface is being absorbed by the continents, by the oceans (seas, lakes, watercourses), and by different plants (this radiation converts into heat, which warms up the atmosphere), while the smaller part of is being reflected. In Hungary, the value of the global radiation at noon with average sunshine in the winter half-year (from October to March) is 250-600 W/m^2. During the summer season (from April to September), it is 600-1000 W/m^2 [8].

THE PRINCIPLE OF THE SOLAR CELL (PANEL)

A solar cell, or photovoltaic (PV) cell, is an electrical device that converts the energy of sunlight directly into DC electricity by the photovoltaic effect, which is a physical and chemical phenomenon. Due to this effect, the light will constantly interact with one of the electrons of the lightened material (metal, crystal) with a particular portion of energy (with the energy of a photon).

The photovoltaic cell is a diode with two different semiconductor layers of interconnected units. The material of the semiconductors is silicon (Si) in most cases, but it could be other material as well. Several kinds of photovoltaic elements exist, but the most commonly used one is the Silicon-based semiconductor. Usually, this is a three-step process (Fig. 5):

- The absorption of light, electrons get into induced state
- the localised separation of positive and negative charges
- managing the charges to get lead into the external circuit.

Absorption (light-absorption). In most cases, it occurs between the absorber and the electron transitions strips of the semiconductor.

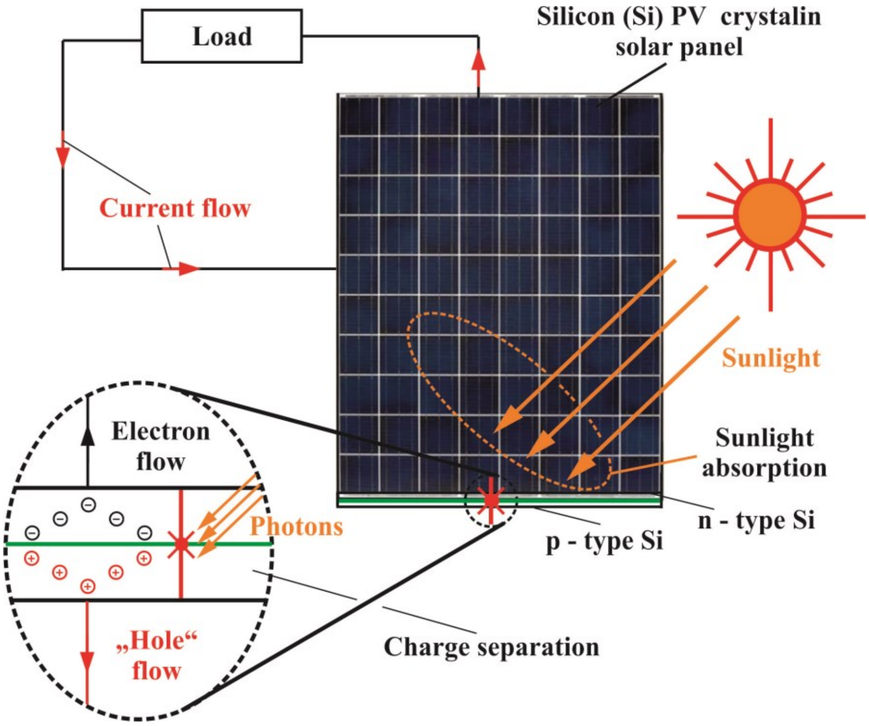

Figure 5: Working method of PV solar panel

The induced state electrons get into the conduction band, while a hole gets into the valence band. The size of the solar panel systems depends on the amount of solar radiation, among many other things, such as the location of the panels and the user demands. The solar panel system also includes the electrical connections, the join tools, power controllers, and the batteries in addition to the solar cells. [2][3]

THE SOLAR POWER STATION SYSTEM IN RÉTIMAJOR

The examined 51 kW_p solar power station is situated in Rétszilas-pond nature reserve, in Fejér county (in Hungary) (Fig. 6). The nature reserve was established in 1996, and its size is 1500 hectares.

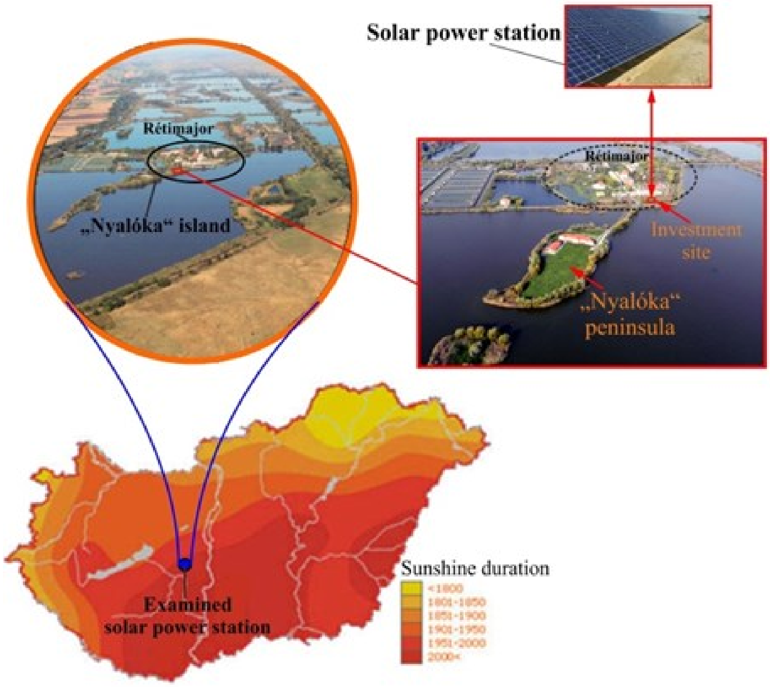

Figure 6: Position of the solar power station in Rétimajor

The activity of these grounds is still a working fishpond system, which was formed at the turn of the 20th century, after the regulation of the Sárvíz valley. The centre of the fishpond system is Rétimajor. It was built by the Zichy earls. According to the winning tender, the investment started during the spring of 2015 in the heart of Rétimajor, at the sites of Aranyponty Ltd. (Fig. 6). The planner and the implementer had to solve the following main tasks regarding the solar power plant (shortlist – without the need for completeness):

- selecting the venue in Rétimajor, considering the orientation of the prospective solar panels,
- creating the plans for the solar power plant with peak power of 50 kWp, being able to feedback to the network, and selecting 200 pieces of 255 Wp PV modules,
- selecting the sufficient number of (3 pieces) inverters and surge arresters for the PV modules,
- the stabilisation of the solar panels and the inverters with a proper rack,
- carrying out the fieldworks and then the implementation of the power plant (Fig. 7),
- starting the test run and then the final operation.

Figure 7: The steps of the implementation in the field

The fixed scaffolding solar panel stand is southern oriented, closing a 30° angle with the horizontal. The initial operation of the constructed small solar power plant in Rétimajor happened during the afternoon hours on the 18th of September, 2015.

POWER YIELDS OF THE SOLAR POWER PLANT

It can be seen from the distribution of the yield (Fig. 8) that the 15th of June (near to the solstice) was a perfect sunny day.

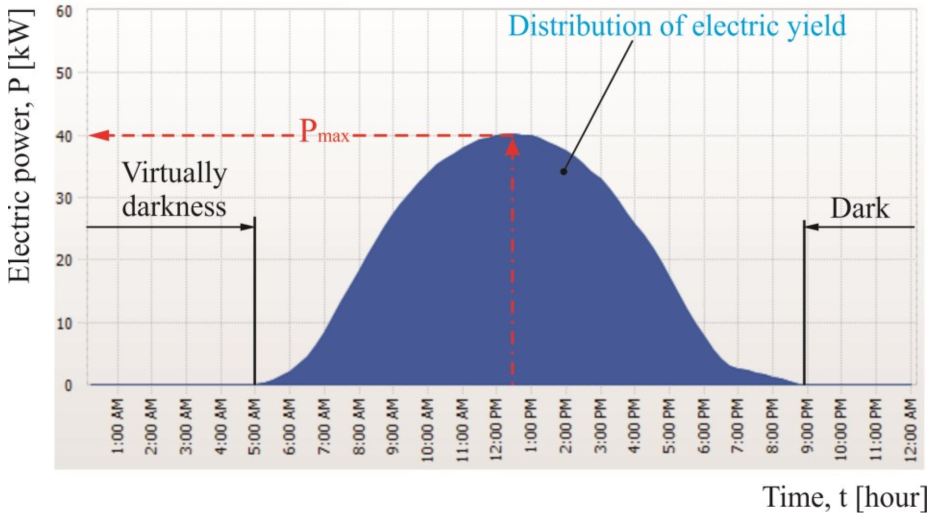

Figure 8: The distribution of the delivered power on the 15th of June, 2021 in kW

Let's take a look at Fig. 9, which illustrates the relations (which is also very nice, with natural distribution) of the delivered power on the 9th of April, 2021. It can be seen that the maximum of the supplied power was nearly 50 kW.

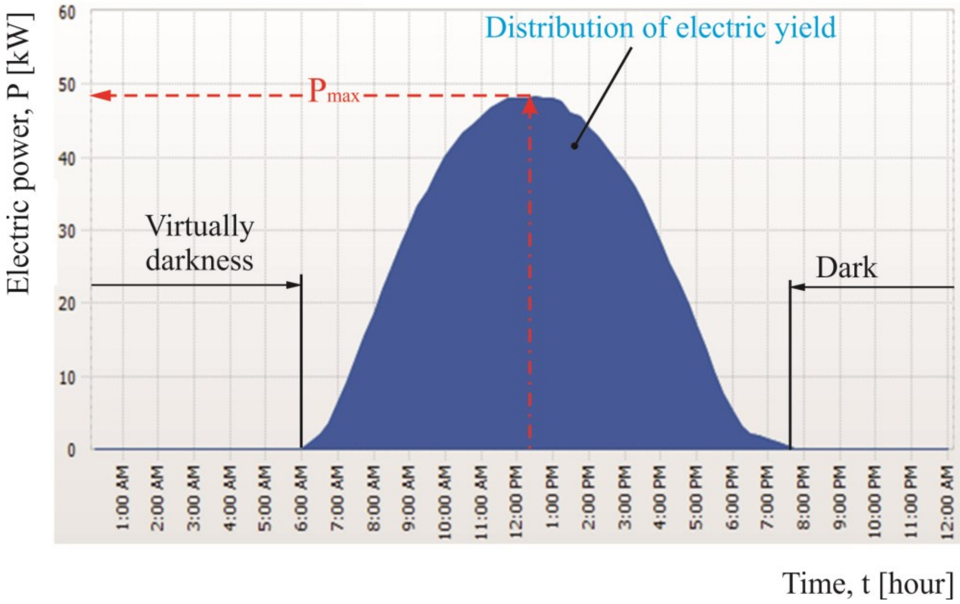

Figure 9: Power data on the 9th of April, 2021 in kW

CALCULATING THE EFFICIENCY, THE PAYBACK TIME, AND THE CARBON DIOXIDE REDUCTION FOR THE SMALL POWER PLANT

The practical efficiency of solar cells can be calculated according to the following equation (1)

$$\eta = \frac{P_{eff}}{I \cdot A} \cdot 100 \qquad (1)$$

where:

- η efficiency [%],
- P_{eff} effective electric power [W],
- I solar radiation [W/m^2],
- A total surface of PV panel [m^2].

The already known equation (Eq. 1) was transformed to energies and substituting the (Eq. 1) results, and we obtained the efficiency.

$$\eta = 14.62\%.$$

The efficiency of the best silicon solar cell can reach 28% in laboratory conditions (STC), while the photovoltaic modules which are available commercially can reach 18%.

The construction of the solar power plant in Fishland was financed mainly from project costs. Because of this, a theoretical payback calculation can be seen below (Eq. 2), so we assume that the total spent net amount was covered by own material possessions.

$$PBT = \frac{TC}{E \cdot P_e} \qquad (2)$$

where:

- PBT payback time [year],
- TC total cost [HUF],
- E total yearly yield [kWh],
- P_e electricity price [HUF/kWh].

Hence the playback time is from (Eq. 2)

$$\mathrm{PBT} = \frac{32\ 477\ 500}{65\ 611.67 \cdot 37.7} = 13.1 \text{ years.}$$

The speed of solar payback depends on several factors. For example, your current energy consumption and send, the amount of clean energy that your solar PV system generates, the cost of your solar PV installation, how your finance your solar installation. Solar is a low-risk investment offering unparalleled financial returns.

Calculation of the CO_2 emission. Considering the measured data, calculating with average 0.67 kg/kWh of carbon dioxide emission. During seven years, the solar power plant in Rétimajor produces 367855 kWh of electricity in total (Fig. 10). The environment was saved from carbon dioxide emissions by 246462.85 kg (~ 246 tons).

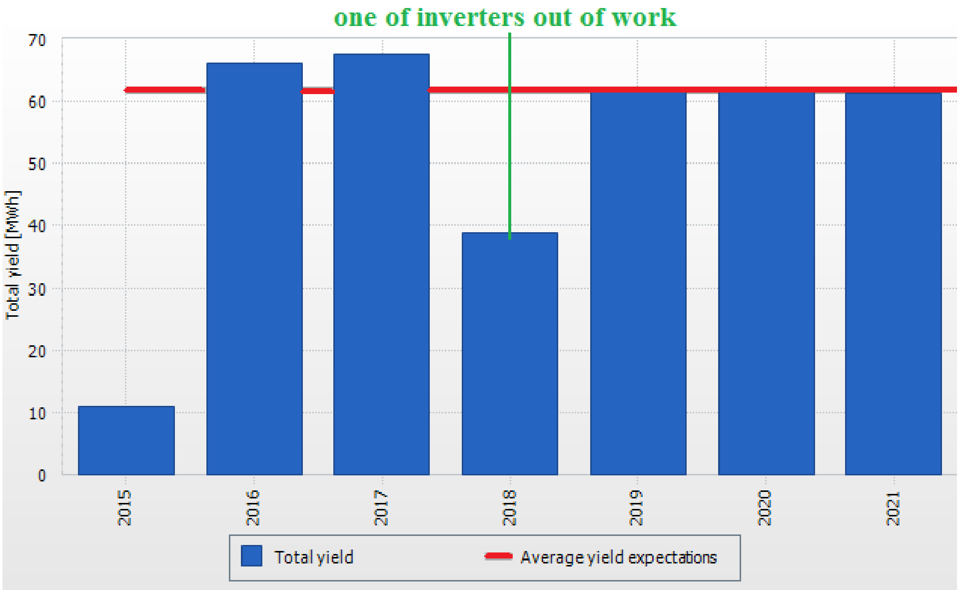

Figure 10: Total yield of the power station from 2015 to 2021 in MWh

CONCLUSION

This paper introduces the solar power plant in Rétimajor. The efficiency of this power station was measured and calculated to determine its amortisation period and the amount of prevented CO2 emission as a consequence of this technology. The measurement and calculation of the efficiency demonstrate that the facility fulfils the committed requirements between 14 and 15%. The various types of solar panels cannot achieve this high rate since their performance is lower and value for money is lower than these attributes of the polycrystalline silicon solar panels.

Compared to fossil fuels, this renewable energy is more environmentally friendly, considering that less polluting gas is generated and emitted into the atmosphere. Combining different types of renewable energy generation (i.e., solar panels completed with wind turbines) could provide a steadier power supply.

These investments are almost impractical from their resources regarding the payback time. Therefore, various public tenders provide financial support for building solar panel systems. The government highly supports these developments. The analysis of this thesis shows that it takes at least 13 years to realise any profit.

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STUDY OF ARTIFICIAL PHENOL CONTAMINATION OF SOIL IN A POT EXPERIMENT

Ágnes BÁLINT, Henrik FÜZES, Csaba MÉSZÁROS

Abstract: *Phenolic compounds represent a large group of molecules and have many functions regarding the aspects of development and the behaviour of the plant. Pot experiments are inexpensive compared to field trials with various experimental treatments without site contamination. After a 14-day test period, the physical parameters of mustard (Sinapis alba), wheat (Triticum aestivum), and garden cress (Lepidium sativum) were measured, but no significant differences were found between the treatments. It has changed the vitamin C content, which is very important in the oxidative stress of plants, as it is an essential material for plant life. For vitamin C, we have also experienced the phenomenon of hormesis. It is exciting how the plant tries to respond to a particular stress effect by changing the content of vitamin C. As a result of phenol contamination, we have been able to increase vitamin C in some concentrations and decrease mainly at higher concentrations, and vice versa. The amount of vitamin C in plants was measured by HPLC. Phenol increased vitamin C content in plants as a stress factor in specific concentrations. By selecting a suitable non-toxic stress factor, vitamin C content can be increased in different plants.*

Keywords: *hormesis, phenol, pot experiment, vitamin C*

INTRODUCTION

Soil pollution with organic pollutants is one of the most common environmental problems, posing a severe threat to people and the environment. Innovative solutions for the remediation of soils contaminated with organic matter deserve special attention [1]. For example, herbicides and bisphenol are most common in agricultural environments. They are often released into the environment due to farming activities and are discharged as wastewater and endangering groundwater, which is also harmful to human health. These substances are taken up by the roots of plants from the soil or their leaves from the air and, if they enter the tissue, can cause severe damages. [2]

Phenol and its derivatives form a large family. In terms of plant development and behaviour, phenol and its derivatives, representing a large group of molecules, have several functions. These include indicator molecules, pigments (e.g., tannins: used especially as dyes), and flavouring substances that attract or repel or protect plants from viruses, bacteria, fungi, and insects. Most of them are present as glycosides or esters and not as free compounds. For example, lignin is responsible for the structural reduction of cells and tissues and is essential for vascular development. [3]

Understanding the uptake and accumulation of organic contaminants in plants is essential to assess human risks. However, scientists have also observed the decomposition of these accumulated substances in plants. [4]

Phenols represent a large family of aromatic compounds, significantly altering plant growth and development parameters. Most phenol and its derivatives have significant toxic effects, manifesting in growth inhibition. On the other hand, other phenol derivatives positively impact growth (e.g., caffeic acid). Phenol and its results affect growth processes and germination, and flowering. Furthermore, they also affect specific metabolic processes such as mitochondrial metabolism. Phenols may themselves have a physiological effect or may affect physiological processes (e.g., auxin metabolism). They act as stressors on plants, thus influencing the number of antioxidants. [5]

Hormesis is a dose-response phenomenon characterised by low-dose stimulation and high-dose inhibition. Hormesis usually occurs in plant species. [6][7]

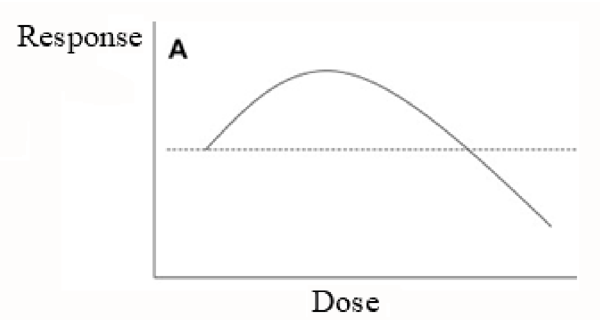

Figure 1: Hormesis A type function in plants [6]

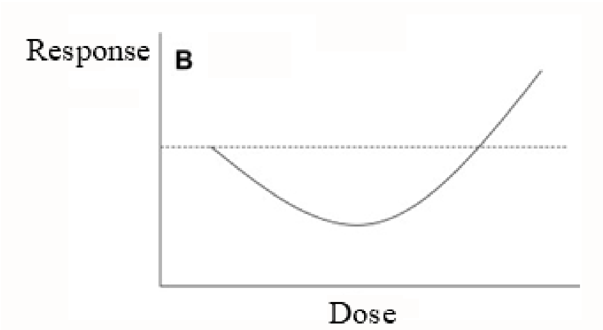

Figure 2: Hormesis B type function in plants [6]

The most common form of dose-response curve is the low-dose stimulating and high-dose inhibitory effect, the inverted U-shaped curve (Figure 1, function "A"). [6]

The other common form depicts the low-dose decrease and the high-dose enhancing effect, the U-shaped curve (function "B" in Fig. 2). [6]

In the following, the areas beyond the "B" curve are again considered decreasing doses, as toxic effects may occur in both cases at higher concentrations. This was observed for both germination and planted plant measurements, even when hormesis occurred in the plants.

Tee's present paper has studied the effect of phenolic pollution in the soil on various plants, and the human risks were also described in case of consumption. Soil contamination was artificial and was investigated for its effects on multiple plants (*Lepidium sativum, Sinapis alba, Triticum aestivum*).

Pot experiments were performed on soil samples with phenol contamination and control samples. After the planting and test period, the physical parameters of the plants and Vitamin C content in different parts of plants (root, stem, leaf) were examined. Vitamin C concentration was determined by HPLC. The results were evaluated using Microsoft Office Excel.

MATERIALS AND METHODS

Soil sampling

Soil samples were taken from the area of Óbuda University (H-1034 Budapest, Doberdó u. 6.). Soil type was Soil Ramanan's brown forest soil. Soil characteristics were measured in the Soil Research Institute [8]. After soil sampling, the soil was air-dried (for approximately 72 hours). The soil was then sieved through a 2 mm diameter sieve. It was further dried at room temperature for 72 hours.

A pot experiment with artificially polluted soil (phenol)

0, 50, 100, 150% of the soil phenol contamination limit (according to 6/2009. (IV. 14.) KvVM-EüM-FVM decree: 1 mg phenol/kg) was chosen for the pollution of the soil used [9]. In three replicates, the pot experiments (in plastic dishes about 20 cm in diameter) were carried out in the laboratory at room temperature. Several seeds planted per pot were: 100. After planting, 50 ml of distilled water was sprinkled daily for a test period of 14 days.

Examination of plant physical parameters

At the end of the 14th day, one-third of the full-grown plants were removed and carefully washed off. Plants were separated into roots, stems, and leaves to measure germinated seeds, the root length and stem length, and the leaf area. After a 14-day test period, the physical parameters were examined using graph paper.

Sample preparation for chromatographic analyses

1g plant sample was used for vitamin C determination. The plants had to be prepared quickly since vitamin C is very sensible for heat, UV light, and oxygen. The frequently used method Furusawa [10] was applied to determine vitamin C, and plant sample preparation was performed according to Lásztity and Törley [11]. First, the roots had to be removed, then 1-1g fresh leaf and stalk were taken into a mortar and crushed with high purity quartz sand till it had given a mashed matter. Then it was transferred directly to a 5 cm3 volumetric flask, and HPLC water was added until the meniscus of the liquid reached the calibration mark. Afterwards, these solutions were filtered through a 0.45 μm membrane filter.

Chromatographic analysis of vitamin C content

The measurement was done by HPLC (type: YL9300 HPLC System built-in Vacuum Degasser Quartenary Pump and UV6VIS Detector 7725i injector with Column holder for mounting the injector/Valve YL-Clarity software for a single instrument of YL HPLC system, PC installed). The measurement was carried out by HPLC-UV was at 254 nm. Vitamin C was separated on a C18 Kinetex column (5µ C18 100 A 150 x 4.6 mm and Security Guard Cartridges C18 4x3.0 mm ID). The flow rate was 1 cm3 min-1; solvent was 2% acetic acid (isocratic system). The chromatographic data processing software was a YL-Clarity data system.

Plants used in the pot experiment

The following plants were used for planting: mustard (*Sinapis alba*), wheat (*Triticum aestivum*) (BiOrganik Online Kft.), and garden cress (*Lepidium sativum*, Rédei Kertimag - Vetőmagkereskedelmi Zrt.).

RESULTS AND DISCUSSION

Plant physical parameters

No significant differences were found between the size of different plant parts (see Figure 2). The half-life of phenol in the soil is less than 5 days [12], but in some acidic soils and soil surface layers, the half-life can be up to 23 days. [13]

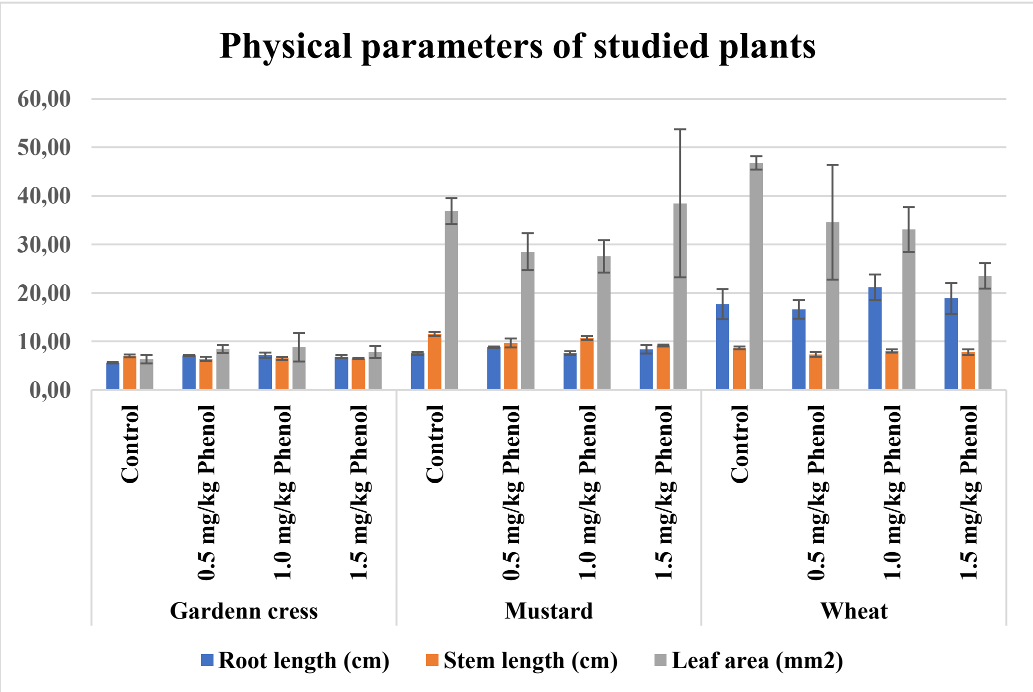

Figure 3: Physical parameters of studied plants

The following questions were looking for the answer: did phenol influence biochemical processes within the plant (e.g., antioxidant balance). Is phenol left in the soil? What effect did it have on the vitamin C content measured in the plant parts?

Vitamin C content in different parts of the plants

Garden cress (*Lepidium sativum*)

The values of the amount of vitamin C determined for 100 g of garden cress (*Lepidium sativum*) are shown in Figure 4.

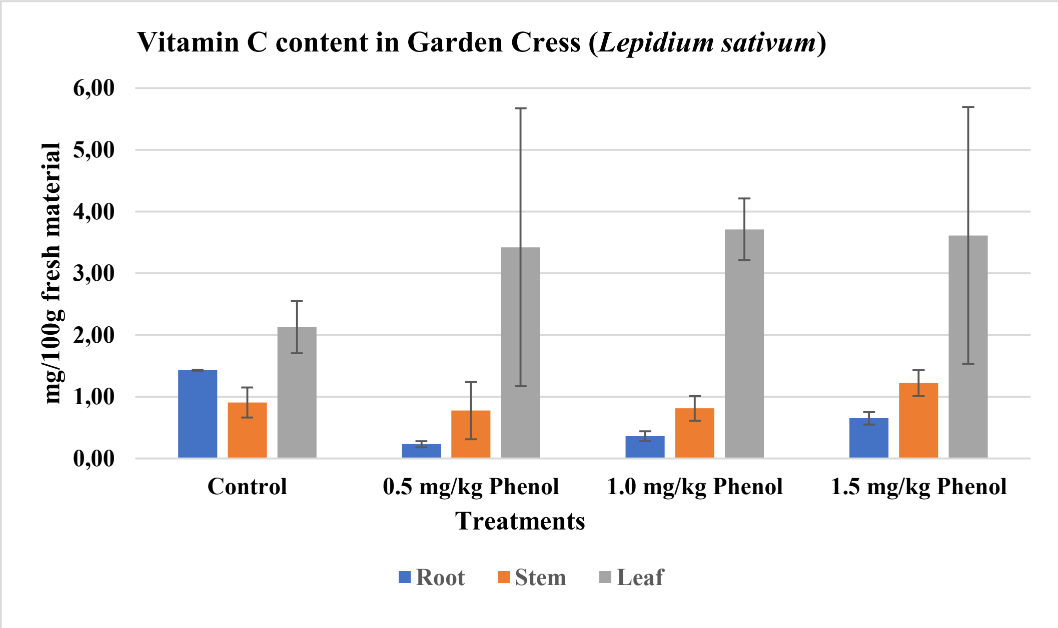

Figure 4: Vitamin C content of garden cress (Lepidium sativum) in 100g of fresh matter

In the case of root: An increase in phenol concentration was not linearly related to the vitamin C content of cress root. The phenomenon of hormesis [6] can be observed.

Based on the dose-response curve, increasing the phenol concentration at low concentrations inhibits root growth to the minimum of the function (0.5 mg/kg phenol in soil). Then, the vitamin C content increases. At the same time, phenol at a specific concentration reaches a maximum from which vitamin C is reduced, and a toxic effect prevails in the plant.

Stem: An increase in phenol concentration was not linearly related to the vitamin C content of cress stems. The phenomenon of hormesis can be observed; however, the curve is blunter here.

Based on the dose-response curve [6], increasing the phenol concentration at low concentrations with an inhibitory effect on stem growth to the minimum of the function (0.5 mg/kg phenol in soil) and then increasing the vitamin C content. At the same time, phenol at a specific concentration reaches a maximum, from which the vitamin C content is already reduced, and a toxic effect prevails in the plant.

Leaf: An increase in phenol concentration was not linearly related to the vitamin C content of the cress leaf. The phenomenon of hormesis can be observed. The changes in the vitamin C content of the leaf can be plotted on the “A” curve (Figure 1) of the hormone phenomenon [6].

Based on the dose-response curve [6], increasing the phenol concentration stimulates the vitamin C content of the leaf up to the maximum of the function (0.5 mg/kg phenol in soil), and then the vitamin C content decreases.

Mustard (*Sinapis alba*)

The values of the amount of vitamin C determined in 100 g of fresh mustard (*Sinapis alba*) are shown in Figure 5.

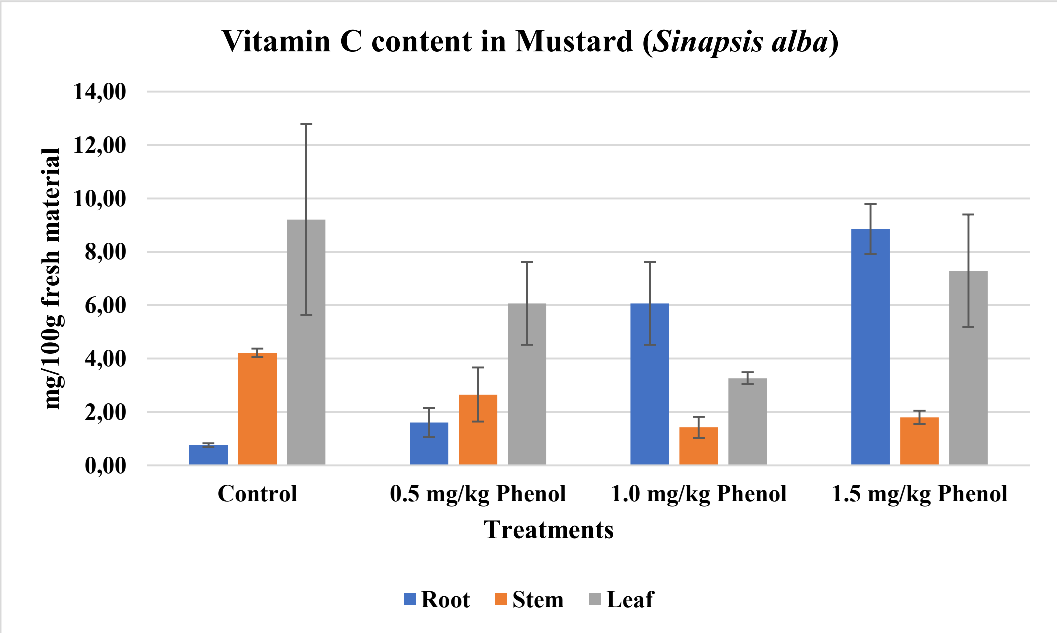

Figure 5. Vitamin C content of mustard (Sinapis alba) in 100g of fresh matter

Root: The vitamin C content of mustard (*Sinapis alba*) roots decreased with increasing phenol concentration. A linear relationship can be established.

Stem: The vitamin C content of mustard (*Sinapis alba*) stems decreased with increasing phenol concentration. A linear relationship can be established.

Leaf: Hormesis [6] is observed in the vitamin C content of the mustard (*Sinapis alba*) leaves as the phenol concentration increases. The changes in the vitamin C content of the leaf can be plotted on the “B” curve (Figure 2) of the hormesis phenomenon [6]. However, a blunt curve is obtained.

Based on the dose-response curve, increasing the phenol concentration at low concentrations inhibits leaf growth to the minimum function (0.5 mg/kg phenol in soil). Then, the vitamin C content increases. At the same time, phenol reaches a maximum at a specific concentration, from which the vitamin C content is already reduced, and a toxic effect prevails in the plant

Wheat (*Triticum aestivum*)

The values of the amount of vitamin C determined for wheat (*Triticum aestivum*) per 100 g of fresh matter are shown in Figure 6.

According to the results, the vitamin C content of the plant increases if the stress affecting the plant is marginal (1.5 mg kg-1 phenol in soil). However, the growth was not intensified. This response of immune reaction confirms that hormesis is measurable and might be generalised. This concentration-dependent biochemical change is rarely studied in detail [6], even though the concept of hormesis has been accepted and widely investigated over the past decade. [7]

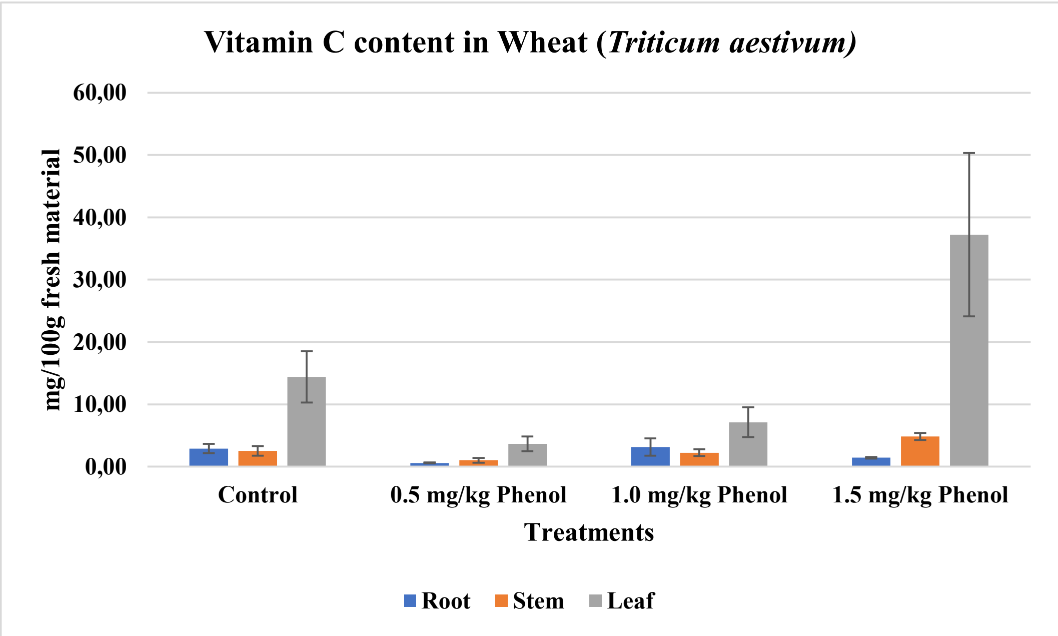

Figure 6: Vitamin C content of wheat (Triticum aestivum) in 100g fresh matter

Root: Hormesis is observed in the vitamin C content of wheat (*Triticum aestivum*) origin with increasing phenol concentration. Changes in the vitamin C content of the root can be plotted on the “B” curve (Figure 2) of the hormesis phenomenon [6].

Based on the dose-response curve, increasing the phenol concentration at low concentrations inhibits root growth to the minimum of the function (0.5 mg/kg) and then increases the vitamin C content (1 mg/kg phenol). The maximum hormesis can be observed here because the vitamin C content decreases. It can be concluded that the phenol concentration of 1.5 mg/kg phenol in soil no longer has a stimulating effect on wheat (*Triticum aestivum*) roots.

Stem: Hormesis is observed in the vitamin C content of wheat (*Triticum aestivum*) stems with increasing phenol concentration. Changes in the vitamin C content of the stem can be plotted on the “B” curve (Figure 2) of the hormesis phenomenon [6]. However, the dose-response curve is quite blunt.

Based on the dose-response curve, by increasing the phenol concentration at low concentrations, phenol has an inhibitory effect on root growth to a minimum of function (0.5

mg/kg phenol in soil). Then, the vitamin C content increases. However, we do not know the maximum of the function here. A phenol concentration of 1.5 mg/kg phenol in soil stimulates vitamin C content.

Leaf: Hormesis is observed in the vitamin C content of wheat (*Triticum aestivum*) leaf with increasing phenol concentration. Changes in the vitamin C content of the leaf can be plotted on the "B" curve (Figure 2) of the hormone phenomenon [6]. However, the dose-response curve is quite blunt.

Based on the dose-response curve, increasing the phenol concentration at low concentrations has an inhibitory effect on root growth to the minimum of the function (0.5 mg/kg phenol), and then the vitamin C content increases. However, we do not know the maximum of the function here. A phenol concentration of 1.5 mg/kg phenol in the soil also stimulates vitamin C content.

CONCLUSIONS AND RECOMMENDATIONS

For selected plants, we would suggest that cress and wheat (*Triticum aestivum*) are excellent for determining phenolic contamination; we would not recommend mustard (*Sinapis alba*) and beans (*Phaseolus vulgaris*). We also applied the measurements to beans, but it developed at a slower rate than germination or not at all. To examine the physical parameters, I recommend several people for a quick examination and the purchase of suitable software for determining the parts and physical parameters of the plants from an image. However, the costs of these procedures are high. The phenol contamination causes oxidative stress on plants, which increases hydrogen peroxide production. Its proportion and amount are proportional to the concentration of vitamin C in the plant. We recommend measuring hydrogen peroxide simultaneously with vitamin C concentration measured with an HPLC device. Regarding plants, phenol can cause hormesis in plants. Hormesis is a dose-response phenomenon characterised by low dose stimulation and high dose inhibition. The most common form of dose-response curve is the low dose stimulation and high dose inhibitory effect, which is the inverted U-shaped curve. The other common form of hormesis is the low-dose reduction and high-dose enhancing effect, which is the U-shaped curve. In the experiments with our plants, we have proved that phenol acts on the physical parameters of the plants and the content of vitamin C with the hormesis phenomenon. We have met with both occurrences.

So, we proved the above effects with pot experiments. Then, we have measured the inhibition of growth of certain plant parts by phenol on plants. Pot experiments are inexpensive compared to field trials with a variety of experimental treatments without contamination of the site. It is easier to observe the possible changes because the contaminants and the material absorption are more pronounced because the soil and root are tight, and the root cannot grow out of the polluted zone. After a 14-day test period, the physical parameters were measured, but no significant differences were found between the treatments.

Phenol did not change the physical parameters, but the changes are significant in the plant's internal processes. It has changed the vitamin C content, which is very important in the oxidative stress of plants, as it is a primary material for plant life. Without vitamin C, the excess of hydrogen peroxide in the plant would kill it. For vitamin C, we have also experienced the phenomenon of hormesis. It is fascinating how the plant tries to respond to a particular stress effect by changing the content of vitamin C. As a result of phenol contamination, we have been able to increase vitamin C in some concentrations and decrease mainly at higher concentrations, and vice versa. No measurable amount of phenol was found in the soil; therefore, the plants took it up, which was confirmed by vitamin C measurements. We can also confirm that it was decomposed over time in the soil samples. According to the literature, the phenol has a half-life in soil fewer than 5 days. The amount of vitamin C in plant samples and a residual amount of phenol were measured by HPLC.

One individual would not suspect at first that phenol, which is a harmful contaminant to the human body on its own, has a stimulating effect on specific parameters in plants. Our experimental plants are fit for human consumption, and their consumption is also widespread globally. Phenol as a stress factor increased vitamin C content in specific concentrations in plants. In today's world, you can hear more and more that the fruit and vegetables available in the store contain far fewer C-vitamins than before. By selecting a suitable non-toxic stress factor, vitamin C content can be increased in different plants.

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THE FORTHCOMING ROLE AND REQUIREMENTS OF QUALITY TECHNIQUES IN THE SERVICE OF QUALITY

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Abstract: *The paper follows the improvement and functional systematisation of quality techniques, an essential component of quality operations. Without these methods, human resources could be used only on an ad hoc basis to support problem-solving and development, remotely approaching the requirements of systematisation, efficiency and goal orientation, or avoiding success to the fullest extent. Throughout this essay, without aiming to give a detailed description, we intend to mention both older and more recent, simple and complex established methods from the previous 30 years and explore current and future demands on them.*

Keywords: *quality tools, process improvement methodologies*

INTRODUCTION

Precise and accurate wording of "quality" is not the goal of our essay; we would merely state, as the essence of the many different definitions and approaches, which will be the starting point of our work. Substantially, "Quality" is an emotionally detectable result of value-added processes created when the stakeholders' minimum requirements are fulfilled or overachieved. If this is not the case, the result is described as "bad quality". That is why quality refers primarily to the result but can also be interpreted regarding the process producing it. These processes are loaded with errors of external and internal reasons, and the solution routines play a part in the organisation's intellectual potential and will be critical to its success.

In any organisations' quality operations – be the organisation a manufacturer or service provider, a for-profit or nonprofit organisation in the broadest sense of the word – problems will inevitably arise. This is when the task has to be routinely carried out, starting from identifying the problem, searching for causes and defining and implementing the final solution until the problem is eliminated. Without warding off the problem, the marketable product can only be created at great expense and loss; alternatively, their processes may become highly resource-intensive. In the best-case scenario, problems may be prevented, and reoccurrence is not possible or significantly less likely to occur. The latter case implies that the processes are designed in advance or modified for the future, translated as a development. In other cases, setting future goals and directions, evaluating circumstances, consequences, and impacts, and the process of achieving them, requires effective human contribution and creative performance based on thinking (together). The presence of probability and its influence on the result is also an increasingly vital component to consider, which further involves risk identification tasks.

The direction of the previous ideas' key subjects (such as quality, problem-solving, product and process development, goal setting and strategy development, risk management) explains that in the period when literally taken "quality management" systems spread (after the 1980s), quality techniques are already mentioned in the standards supporting the system standards (e.g. ISO 9004-4: 1993,…).

In passing, the collective noun of "quality problem-solving techniques" commonly used in Hungarian is fundamentally flawed, as these techniques do not solve any problems neither independently nor together. They only moderate, structure, visualise or help with group analysis, contributing to working out the most appropriate solution. In other words, it is better to depart from the English term "tools".

THE IMPORTANCE OF BASIC TOOLS AND COMPLEX TECHNIQUES

7QC, as a "starter kit"

During the historical period mentioned in the previous chapter, all quality management training courses devoted a great deal of energy to present a "starter kit" that helps solve problems, involving to a greater or lesser extent in practical implementation. This was later referred to as the broad terms of "7QC, i.e. 7 Quality Control Tools" or "Seven Basic Quality Tools" or "Quality Management Tools". Today, the situation has changed so much that by incorporating these tools into graduate higher education curricula, mainly in technical or economic fields, the basics of quality management can be thoroughly learned, so that the content of external professional training courses can quickly skip these and newer techniques can be incorporated in the schedule of training.

Concerning the content of the "starter kit," the literature is diverse to some degree, but the same 5-6 tools form its core. These 7 techniques, using their original terms, are the following 8(!) most of the time [1]:

1) **Check Sheet:** A tool described as a data table, where values of case numbers forming a simple or complex problem are primarily grouped in a table according to different criteria (e.g. specifications, conditions, raw materials, technological settings, etc.).

Specific 7QC citations choose a fundamentally visual method of multi-aspect classification instead of a tool called Check Sheet. This method carries a similar message by analysing the timeline of the Control Chart method. These are stratification diagrams.

2) **Stratification diagram**s are visualised by our simple MS software, drawing a diagram. Excel visualises them as a timing diagram with colour-separable points.

3) **Flowchart:** a unique graph giving a simple description of a process, using a standardised symbol system usually, which may show less variation depending on the profession, possibly due to the software used, but can be easily adapted. Suitable for the assignment of processes and their internal dynamics (junctions, feedforwards and feedbacks,…) and the external relationship system - e.g. documentation, executive personnel, etc.

4) **Pareto Chart:** represents the effect of a quantified problem (traced back to the causes) in descending order and on a cumulative curve. Shall be preceded by the identification of causes and quantification of effects.

5) **Cause and Effect Diagram:** A common technique became to be known by its typical fish skeleton shape, which helps by exploring and classifying a causal system that generates a problem (cause-and-effect diagram, Ishikawa diagram, Fishbone diagram). Shall be preceded by a group brainstorming and classifying session.

6) **Scatter Diagram:** Scatter Graph, Correlation Chart, or Scatter Plot. In reality, it is unfinished regression analysis, showing data points only. Enables an "intuitive" visual examination, including the direction of relationships, trend type, and deviations. Allows involving those who are not proficient in regression and correlation analysis in the effective identification and investigation of correlations.

7) **Histogram:** A well-known tool for characterising the frequency of quantified data. It is a commonly used statistical method facilitating the visual assessment of the probability density distribution of numerical data. Histograms are already included in secondary education curricula. It allows a graphical shape that differs from the statistically "okay" data sets with obvious distribution to be noticed and provides a high chance that a change of potential concern can be spotted.

8) **Control Chart:** On most occasions, control charts are suitable for representing a numerical characteristic (product specification, technological condition and quantitative data of discarded items and failure events) to which a time series refers. Additionally, they are often used for the metrological analysis of measuring systems, typically shown as diagrams, which are always complemented with different limit values. Regular control procedures may be initiated based on the conclusions drawn from the behaviour of the data points. This tool is just a step away from problem-solving. If it has been introduced as a system, it is constantly being applied. Based on visual assessment, it always answers whether the data stream is in a statistically different condition than what has been accepted previously. If this requirement is not fulfilled, an intervention shall be implemented, or at least closer supervision and additional analytical observations should be made.

A flowchart may be a basis for preparing process documentation with different functions by resources supporting management systems in organisations. Illustrating the process itself would be an end in itself. Therefore it is always associated with a function to help the quality operation (e.g. hazard analysis for HACCP, preparation of mass balance for process elements, process decision program chart, control plan, etc.)

The phase-in and application of control charts in sectors requiring higher accuracy may be part of the system requirements prescribed by a standard or directive, and suppliers may be obliged to comply with their customers.

Compared to other simplified tools, the control chart is a significantly more complex, much slower recoverable tool that requires mathematical-statistical knowledge and is unsuitable as a “single-use” method. It shall be operated in cooperation with the processes. Therefore, the control chart among the 7QC methods is not just a tool but a complex methodology that must be operated continuously, including all elements of the PDCA that can be associated with the managed data.

That is why the 7QC methodological repository is not a toolbox organised according to internal logic, but a set of tools often used and proven in the operation of organisations. Kaoru Ishikawa had developed the toolbox during the period of Japanese industrial advancement. It has been serving - ever since - simplicity, efficiency, and active engagement in teamwork, even for the lower-qualified personnel. It is no accident that the techniques used in Six Sigma, LEAN, or TQM methods by advanced organisations also embrace this set of tools called the “gold standard”.

Other components of the basic toolbox

Quality management often uses techniques that mimic a “tree” structure and make a hierarchical structure visible — **TREE diagrams** —, while performing an analysis. According to the rules of creation of written materials, diagrams are reminiscent of a root unfolding from top to down or a converging canopy, the branches of which show causal chains (event tree), or the system of “root causes” (FTA or **fault tree** analysis). **Assembly trees** make the logical network of the convergent nature of separate parts, intermediate and finished products visible.

The **decision tree** is commonly used in HACCP systems. Although named as “tree”, it mostly reminds of the decision system of a flowchart. In this case, it is necessary to decide whether it is a critical control point (CCP) or not by going through the logical T/F questions of the tree.

According to a proven scheme, specific questioning methodologies can convert basic tools (e.g. Ishikawa diagram, fault tree, etc.) into an analysis. **5W**, with a chain of "Why?” questions repeated five times, tries to find the root cause of the problem, helping in creating a transparent error tree (for example). [2]

One or two “H”s written after the “5W” could be used to explore a complex network of circumstances, so in addition to the first five W (who, why, what, when, where), “how” (5W + 1H) and/or “how much/many” is also included (5W + 2H), hoping to explore the roots of the problem fully. [2]

Other modern techniques in the service of quality

Internet forms Nowadays, easy-to-use, freely programmable, cloud-based, simpler-to-complex questionnaire applications and software provided by the commonly used Internet content providers have become widespread, collecting and processing information from a larger circle of respondents, mostly regardless of location or time. The possible technique used for the survey or interview is performed by the software, the selection of designated persons, the specific questions, and the interpretation of the data are performed by the operator/creator. In addition to the quality of the questionnaire, the operator's/creator's responsibility also applies to legality, data security, and regulation. It is not explicitly a quality technique, but as it is already suitable for getting to know stakeholders' opinions, understanding the history of developments, or feedback on the results, it can belong to this group.

Another similar Internet and cloud-based application is the **Mentimeter**. In response to a public question (e.g. at an event), the participants vote using their mobile device in real-time on the proposed solution, answers, or evaluation. This is also not a typical quality technique. Still, immediate processing of questions and answers concerning quality issues can be implemented and thus can be effectively used in some cases. [3]

This essay makes no mention of methods used to stimulate and moderate group thinking, such as brainstorming and brainwriting techniques. Any school or training teaches these and focuses on leadership skills. Staying true to our title, we would like to mention a novel methodology in this area, the "**World Cafe**" method, which is about to become prevalent recently and bears most marks of the Delphi and Philips 66 methods. It can entice a company of 30-50 people into brainstorming-like creative thinking without exceeding the optimal group size of 5-8 people. Next to the so-called "tables", in a fixed topic, the permanent "table hosts" also moderate the work of the rotating teams and make a summary of the approx—a 10-minute active period which was spent there by each team. The outcomes on the same subject of the rotating table companies are then extracted from the remaining table hosts, and from these essential collections at the end of the work, each host reports publicly to the entire company that had been gathered together by then, sharing the ideas that had been uttered separately. [5]

The following methods use several techniques (e.g. selected from 7QC), including a deeper analysis, to obtain a more profound analysis.

Complex methodologies acquired by mixed using of quality tools

The previous chapter listed tools, but the aspects of being chosen as one of the 7QC were not clarified, and only the given situation will decide which application is appropriate. However, each of them is suitable for only one step of the analysis, except for the Control Chart methodology, which is therefore considered an exception.

On the other hand, quality management needs well-established and mostly harmonised, almost "standardised" methods that can "choreograph" the entire process from detecting a problem to a tried and implemented measure that had become a routine practice to solve a problem. These new techniques can be traced back to the original PDCA cycle.

Regardless of the specific techniques, the following complex methods have a few common features:

- Occurrence of a condition, event, or situation other than the commonly accepted standard.

- They are generated by reaching the internal "threshold" of the organisation or by the external motivation on the part of the customer. This threshold is mainly related to the most significant, actual or potential financial loss.
- They have significant economic or security aspects.
- Throughout the steps, they use more accessible techniques creatively, for example, described in 7QC.
- They also use 5W and 5W + xH methodologies to explore the causes of problems.
- When applying the techniques, teamwork is needed.
- They do not focus on problems that had developed individually and isolated, but on regularly recurring issues (or potentially several times).

5S is a method named after the initials of steps in Japanese. It helps maintain the technological order, discipline, transparency and thus indirectly the efficiency of a workplace or workflow. While the first step of the PDCA does not yet, the last one by establishing regulation/monitoring, necessarily reflects the approach. The sixth S (safety) has been generalised by some companies since the introduction of 5S. However, it seems to be the odd one out regarding the original concept. This is not a new step with a Japanese initial, but an emphasised aspect of security integrated into all Ss throughout the entire process. It is particularly beneficial for companies where the instinctive pursuit of occupational health and safety is made part of an already implemented management system (OHSS).

QFD, which has been evolving since the 1970s, has become more widely used and popular for deploying the quality functions with which the customer's simply articulated, quality-embedded and weighted requirements are connected to the "technical" parameters that could influence implementation. The focus is on developing current or new products and manufacturing/service processes. Naturally, the customer may be freely interpreted as an external and internal customer at any point in the supply chain. This complex technique also includes another visually structured technique called **HOQ** - House of Quality. Its typical structure consists of the rows as customer claims, the columns as technical characteristics (product or technological specifications), the matrix evaluating their relationship, and the customer and benchmark data assigned to these rows or columns. The result is a conscious reflection on requirements, claims, and influencing characteristics, which is just as a positive outcome as the acquisition of empirical data from external sources, as well as the setting of priorities of intervention or the target value of the parameters of the elements that should be developed. [7]

8D is a specifically problem-solving methodology, covering the entire cycle of PDCA in a process-controlled and documented implementation (8D routine). The process is initiated by a customer complaint. The strict timing of the initial steps is crucial, similarly to customer cooperation and keeping in touch regarding reporting and approvals during each step. Throughout this eight-step process, from the precise definition of the problem through the organised identification of root causes, the main goal is to find and implement a solution that can be integrated into the system. In addition, fast mitigating actions on the problem and their subsequent review and continuous documentation are still needed. Reaching the "closed" state of the procedure as soon as possible is an essential requirement to the organisation that does not pile up semi-completed corrections and improvements. For these processes, which are considered as smaller or larger projects, the ratio of the achievement of finalized states within a certain period can be used as an indicator of the quality system in organizations. [6]

The **A3** methodology is very similar to the previous one, notedly an improved version of it, and in several larger companies it can be considered as a minimized version of its documentation, the basic concept of which is the same as the full PDCA. It does not have to be connected to a particular customer complaint, it is suitable for solving a defined problem arising from any direction. The description of a "defined problem" is explained at the beginning of this chapter. The meaning of the name (all steps should be documented on a maximum of A3 sheet of paper) shows the most important goals of the technique: conciseness, documentation, sistematically implemented PDCA, thorough understanding of the environment and root causes, and improvement throughout 7 steps. [4] These 7 steps in a nutshell are:

- a description of the **background of the origin**,
- **assessment of the current situation/state**, understanding of the problem, showing the differences between the plan and the actual state,
- **specifying the goal to be achieved**, with indicators ensuring measurability or the name of the status,
- **analysis** in which the most critical task is to determine the root causes,
- **suggestions for implementation alternatives** and assessment of multi-aspect selection criteria and decision
- developing a **plan** for the implementation of the chosen solution, specifying indicators indicating the implementation and its level, and
- **monitoring** implementation, communicating results. [4]

Compared to the initial 8D method, A3 attaches more importance to understanding the problem, describing it accurately, and identifying its causes. However, its documentation is much more straightforward, modest, and uniform. Most of the essential qualities and techniques of group work listed earlier should be appropriate to fulfil the steps, depending on their function.

Also gaining ground in the automotive industry, the **Dorian Shainin** methodology is a much newer member of the 8D-based procedures. It is also based on the full PDCA circle and uses abound, simplified "choreography" from revealing the root cause of the problem to implementing it in similar processes. However, it is suitable for most technical conditions of part production. The methodology also strives for conciseness and utilizes simple basic techniques searching for root causes and visualizing while requiring group thinking.

As a novel feature, it looks for the causes (RED X) of the effects (GREEN Y) described at the beginning of the procedure, defined as product defects, i.e. defective part, incorrect machine setting, material, environmental condition,… Besides, his motto is to sort out RED Xs identified as root causes through a series of steps of observation and obtaining evidence while working. During the observation, the differences can be identified through a thorough comparative observation of the problematic and good parts, and then solution possibilities, tests, and simulations targeting the RED Xs will lead us to solve the problem. The process also follows a typical 7-step choreography marked by the initials of "F.A.C.T.U.A.L." [8]

1. The **Focus** phase, apart from defining the problem, also captures the conditions of problem discovery as accurately as it is possible, which serves as a starting point for the following in-depth analysis.
2. The **Approach** phase approaches the green Ys (which appears to be the cause) through selection and analysis. Preceding the next step, this phase is more of a definitive step, aiming to clarify the testing strategy.
3. The **Converge** phase consists of an in-depth analysis of the causes, i.e. a series of red Xs are revealed.
4. The **Test** phase examines the designated, potential red Xs to see if they are correlated to the origin of the problem. If this phase fails to identify the cause (i.e., X is not the cause of Y), we shall return to the previous, approximating phase to the next potential red X. As for the identified red Xs, we move on to the subsequent phases intending to solve the problem.
5. During the **Understand** phase, the relationship of the identified X-Y pairs must be "understood" and, based on this, the elimination of the Ys by modifying the Xs must be planned.
6. Along with the **Apply** phase, the implementation of properly selected plans follows a controlled process.
7. Finally, the **Leverage** phase closes the process by defining the extent to which a minor correction or development has resulted in an improvement. The next step is to transfer this improvement somehow to another process struggling with an (assumed or proven) similar problem.

LEAN and Six Sigma philosophies apply many accomplished techniques of low or greater complexity. Moreover, the LEAN approach expropriates the best methods according to its terminology and uniformly refers to them as **LEAN techniques**, although they had often been used in the past in an unchanged or modified form to analyze or solve problems. These techniques could be discussed in another separate publication, and this group is evolving on its own by adding new, effective methods to the toolbox.

A main feature of the latter two techniques is the logic of DMAIC (Define - Measure - Analyze - Improve - Control), which serves as the "engine" of development. It follows precisely the train of thought of the original PDCA but clarifies the oversized (therefore less defined) phases of the Plan step. As a result, it defines the starting point for developing more specifically and significantly separates the description of the problem from the observations and analysis of the information obtained. The rest of the Deming cycle ("DCA") is already more closely related to the process expected in LEAN methodologies ("IC").

EXPERIENCES OF THE CONDITIONS UNDER WHICH THE TOOLS ARE USED

"Homo habilis" using quality tools and the development of organizational culture

As a general experience, the problem-solving potential of organizations is highly dependent on the extent to which active participation and engagement in teamwork is comprehensive; it is also influenced by the knowledge base on which it is established and by how much forms a part of daily practice. The participation and number of employees involved in the relevant training increase the problem-solving ability and teamwork efficiency in defiance of the resources, expended. Thus, where the role of teamwork collaboration significant because of the manager's will, the field of application and the affluence of the techniques is also bigmore extensiveut obviously, the economic benefit might also be demonstrated. At the same time, more modest management skills or moderate commitment to the topic does not bring about or extinguish the natural tendency of employees to use quality techniques. In an unfortunate case, which might cause a significant error cost, if the "cultural attitude" of the organization wins a more developed partner among its customers - such as an automotive industry leader.

Supplier quality professionals handling complaints often complain about the fact that one party (typically the customer) requires the supplier to use 8D or more advanced solutions, but the supplier still tries to grow up to the challenges of Ishikawa or Pareto analysis, or fill in a histogram with appropriate data.

What makes a quality tool?

Beyond 7QC, it can be seen that the term "quality tools" is a set that is open from above and the technique used does not fundamentally determine for a thinking aid tool that it can only be used for the purposes of quality management. In other words, it can be stated briefly that **anything has the potential to become one** as long as it seems to work well in the eyes of authoritative quality professionals and helps their work effectively. The above were examples of essentially any simpler or more complex method helping thinking – should it come from e.g. the fields of sociology, pedagogy, economics, psychology, or technology – has the potential to be included in the compilation of "quality tools" that can be used effectively in one or more phases of the problem-solving process to improve the product or process quality. These tools are mostly able to facilitate teamwork today and in the future as well.

THE LATEST REQUIREMENTS AND DEVELOPMENT TRENDS FOR APPLICABLE TOOLS AND TECHNIQUES

Quality tools should support the process in cases where there is either a problem arising or a development becomes necessary, starting from the current state. Among the requirements for the newly developed quality techniques, we now consider the compatibility with modern IT technologies and the increased disengagement from the constraints of time and place regarding the participation in teamwork activities to be of paramount importance.

- It should facilitate quick learning and be easily carried out even without a trained moderator.
- It should promote clarity using simple questions in order to bring forth simple, straightforward answers.
- It should lay out a structured list, where the next step guarantees that previous ones had been fulfilled. Consequently, the amount of work won't scare off anyone and it is easy to understand and follow its progress.
- It enables document creation simultaneously while working on the subject (no need to take notes or record to another platform or application, in parallel in typescript or in a handwritten form). Also fosters procedures of processing, documenting, or approving analyses and their results.
- In the form of a computer or mobile application, it should be distinguished by a common design, operation, and appearance, with free cloud-based access.
- It should be able to function on portable devices, achieving a high level of mobility.
- Compatibility with other applications used in the field of quality tools, possibly databases.
- Parallelly with mobility and compatibility, the solution of the security and authorization aspects of the data and images recorded with the applications is of particular importance.

In the long run, we might assume that three specific phenomena can be discovered and envisioned in terms of the change and improvement of methods:

1. One of them is that involving colleagues in problem-solving, making the problem visible and easy to consult, extracting creativity fundamentally requires the same techniques due to the mechanisms of human thinking (such as the behaviour of consciousness and the psyche) and the **relative inertia of the base culture**. That is why the same techniques have been proven to be effective for a long time. These are, for example, the unchanged applicability of 7QC, brainstorming techniques, PDCA approach, pragmatic search for solutions, etc.
2. **Technical support provided for thinking and creativity is changing at a rapid and even increasing rate.** This technique is of great help in visualization, locating sources of problems of technical origin, during and after group work, and ensuring the availability of data and information at work.
3. And **the most radical change is expected in the subject of teamwork**, about what could creative problem solving be applied to. As robotization is becoming increasingly widespread, the amount of human operations in manufacturing and services is declining rapidly, shifting the focus from a more unpredictable human component to a machine component that is easier to find out and troubleshoot but already may be avoided at design. To put it another way, solutions to mistakes made in the planning process will also become a priority in terms of their importance and frequency, as human operations will be found in fewer and fewer areas. With the rise of "smart" tools and systems, part of the solution to in-process problems will come with the increasing involvement of artificial intelligence. Nevertheless, from an operational level that produces a product

and provides a service, beyond the level of the process operator, problems requiring human assistance arise at the design and management level.

CONCLUSION

Based on our previous experience and throughout our work, it has become obvious that methodologies referred to as “quality techniques” in technical jargon form a set that has no explicit phase separation and is constantly expanding. Our finding is even simpler: anything can be used to solve quality (or other areas’) issues, as long as it is applied effectively.

However, in line with current trends, we have tried to predict (and possibly envision) the future tasks, requirements, and application points for these techniques in order to be mentioned by professionals as methodologies that are of great service to the quality products and operations of organizations.

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ADDITIONAL LITERATURE

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OPTIMISATION METHODOLOGY FOR STRUCTURAL DESIGN OF THERMOELECTRIC MODULES

Judit ALBERT, Edit CSANÁK

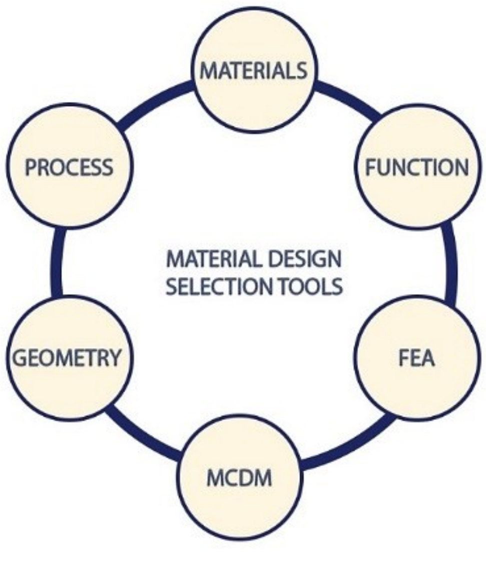
Abstract: *Nowadays, concerns related to humanity's increasing and destructive impact on the environment have influenced and changed the paradigms of product development; this, in turn, has brought about the appearance of environmental considerations in the creation and design of new products. Numerous industrial sectors have changed their product development and production processes to meet ecological requirements. This article presents a method of comparing new alternatives with a specific decision-making methodology.*

Keywords: *design science, design methodology, alternative materials, contemporary design, sustainable development*

INTRODUCTION

Design problems can occur in a variety of ways. Before anything happens in design science, tools for classifying the design task need to be developed. [1] Considering the specifics of the designing tasks related to thermoelectric appliances, the efficiency of assessing the suitability of the designed devices for different tasks is of decisive importance for the decision-makers involved in elaborating the modernisation and development tasks. Selecting the most appropriate alternative for a given, often particular task is complicated, time-consuming, and costly because complex relationships and multiple-choice parameters must be examined simultaneously. The article presents the ranking between the different alternatives during the research and development (R&D) process and the method of selecting the most suitable option.

DEFINITION OF ELEMENTS OF THE DECISION MODEL



Decision-making is a critical point in development and modernisation processes. Based on the available data, the decision-making process should be approached, focusing on aligning the requirements and capabilities with the designed devices. Figure 1 shows the general method for comparing thermoelectric devices using multi-criteria decision procedures. [2] In this study, there are 4 criteria, and 4 alternatives ranked based on the VIKOR method. [3]

Figure 1: MCDM as a material design, selection tool

The mathematical basis of the algorithm is presented below. The solution of the problem is possible using a multi-criteria decision-making model; its model is given by equations (1) and (2):

$$\begin{array}{ccccc} & & A_1 & \dots & A_n \\ C_1 & w_1 & u_i\ (a_{11}) & \dots & u_1(a_{1n}) \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ C_m & w_m & u_m(a_{m1}) & \dots & u_m(a_{mn}) \\ & & x_1 & \dots & x_n \end{array}$$

(1)

and,

$$y_j = \sum_{i=1}^{n} w_i u_j\left(a_{ij}\right) u_{(x)} \quad (2)$$

were,

A_j: *j*th alternative.

C_i: *i*th aspect.

w_i: weight of the *i*th aspect.

a_{ij}: the value of the *j*th alternative *i*th aspect.

u_i: the evaluation (utility) function for the *i*th aspect.

x_j: score of the *j*th alternative (ranking). [4]

EVALUATION CRITERIA

In the decision situation examined in our example, the decision-maker evaluates a finite number of alternatives based on a limited number of criteria. The most basic in evaluating alternatives aspect to be considered is effective construction design. Another vital aspect is utilising the mechanical properties of the materials used. Another essential part is the more significant the reliability of the alternatives and, at the same time, their guaranteed service life. The structural utilisation can measure the uptake of the optimal load of the reinforcement alternatives, so the over-or under-sizing resulting from each design can be given at this point. The problem of sustainability is not a negligible consideration in the evaluation either. (Table 1) In a low-temperature range, copper iodide (CuI) is a promising candidate using pellet material in thermoelectric modules as a low toxic and Earth-abundant material. (Figure 2) CuI can be a potential alternative to the commercially available low-temperature TE materials, in this case, such as bismuth telluride (Bi_2Te_3). [5]

Table 1: Aspects considered in the process of comparing the alternatives and their importance values, and the decision matrix

Criterions	Evaluation of criteria
C1 material utilization	0.4
C2 Reliability	0.2
C3 Sustainability	0.3
C4 Construction design	0.1

Table 2: Decision matrix

Decision matrix (Expert 1)	**C1**	**C2**	**C3**	**C4**
A1 – Pellet CuI, Filled cubic shape	0.4	0.2	0.2	0.3
A2 – Pellet Bi_2Te_3, Hollow cubic shape	0.3	0.2	0.4	0.1
A3 – Pellet CuI, Filled trapezoidal shape	0.2	0.3	0.2	0.1
A4 – Pellet Bi_2Te_3, Hollow trapezoidal shape	0.2	0.2	0.2	0.2

By processing the models of the created alternatives and the results of the finite element load simulations performed on them, the other options were ranked in an Excel implementation using the mathematical model of the VIKOR method. The results of the evaluation process are shown in Table 2. Alternatives are denoted as A1, ..., A4 and aspects by C1, …, C4. Table 3 presents the ranking list for the other options based on the S, R, and Q values.

Table 3: The ranking list for the alternatives

Alternatives	**Criterions**									
	C1	**C2**	**C3**	**C4**	**R-value**	**Rank in R**	**S value**	**Rank in S**	**Q value**	**Rank in Q**
A1	0.696	0.436	0.378	0.775	0.3	2	0,5	1	0.25	2
A2	0.522	0.436	0.756	0.258	0,2	1	0,5	2	0	1
A3	0.348	0.655	0.378	0.258	0,4	3	0,8	3	0.833	3
A4	0.348	0.436	0.378	0.516	0,4	4	0,95	4	1	4

Considering the sources of the complexity of the task, we examined the complexity of the design task. We can see that each task has dimensions of task complexity for which decision making can be supported using the mathematical model of the VIKOR method.

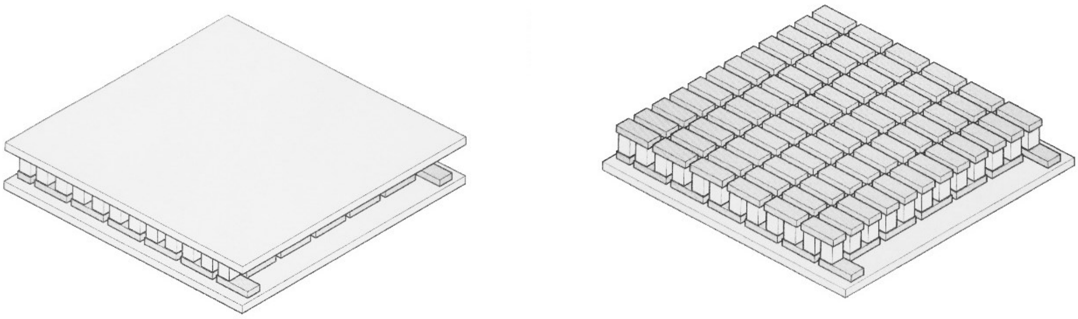


Figure 2: Schematic illustration of thermoelectric modules

SUMMARY

As a result of the ranking of the VIKOR method, the second alternative (A2) had the best ranking of the alternatives, and the fourth alternative (A4) was the one that came to the end of the ranking. Therefore, A2, A1, are selected as the final alternatives. During the evaluation, it can be stated that one of the disadvantages of the method is that the result only gives a ranking between the alternatives, so there is not enough information about the size of the difference between the alternatives, so the decision-maker gets a particular ranking but no information about the differences. Therefore, it would be helpful to use the AHP (Analytical Hierarchy Process) to develop further the methodology, which will also make this information identifiable, thus increasing the adequate support of decision-makers.

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RISK ASPECTS OF THE REGRESSION APPROACHES USED IN THE EVALUATION OF TDM TEST RESULTS

Tibor GREGÁSZ, Veronika PÁL

Abstract: *Our previous research was carried out to determine the measurement uncertainty of TDM test results, so as to contribute to the CE conformity assessment of cut resistant gloves. According to the standard, at a given point of the test method, the assessor chooses a regression curve to characterize the paired values. This empirical decision also alters measurement uncertainty, affecting the risk of not reaching a limit value, as well as the risk of the classification of protective performance.*

Keywords: *cut resistance, measurement uncertainty, risk, regression analysis*

INTRODUCTION

Protection against mechanical risks – including resistance to cutting by sharp objects – is assessed by test methods such as the TDM (Tomodynamometer) test, which provides results supporting the classification of protective gloves. Classification is performed by a series of measurements of realized cut-throughs, followed by a relatively complicated mathematical procedure and a classification by a scale. In the case of this product type, the scale is defined by the currently EU-wide applicable standard EN 388:2016+A1:2018. [1]

That is why the measurement error of the test method obviously falls into a high risk category, so careful analysis and assessment of the components contributing to the measurement uncertainty was of paramount importance in our previous publications. Throughout the steps of the method (which will be described briefly on the following pages), the effect of selecting a regression curve – which parametrizes the relationship between the compression force affecting the knife and the cutting length – has already been mentioned as one of the uncertainty factors, but its numerical analysis has not yet been performed. This article is based on a numerical analysis of this factor's influence on measurement uncertainty and on the risk of performance level classification.

PRINCIPLE AND BRIEF DESCRIPTION OF THE TEST METHOD [2]

According to the relevant standards, the extent of the downward force shall be determined, which force is required to cut through a fixed and supported specimen with a displacement of a specified length. The obtained result expresses the force applied to the blade in a perpendicular direction to the cutting edge, which cuts through the test specimen at a distance of 20 mm. When the cut-through occurs, the device contacts the supporting copper strip by closing a circuit and also signals the end of the intersection to the evaluation unit.

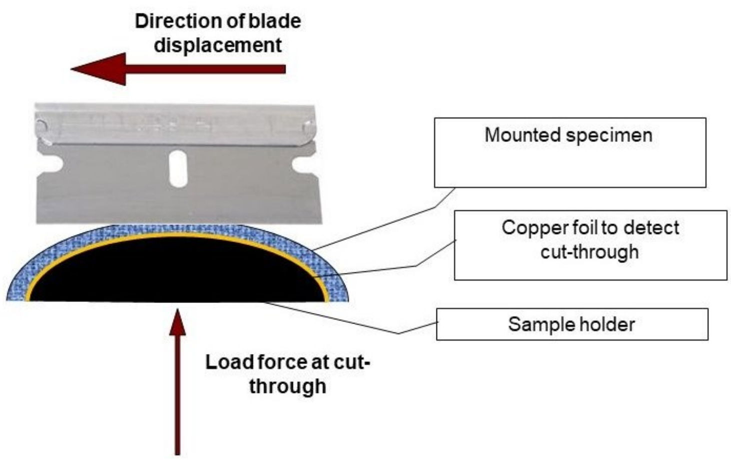

Figure 1: Schematic drawing of the TDM test method [3]

The test procedure:

1) The specimens are mounted on the curved specimen holder (providing solid support), as shown in Figure 1. Then the blade is pushed forward using the previously untouched cutting edge by the force value which has been set. (Figure 1.)

2) To eliminate production standard deviation, a standardized correction factor of "sharpness" must be calculated for blades from the same batch. This is done by cutting through a neoprene calibration material with standardized properties.

3) The measurement results obtained on the test sample are multiplied by the correction factor specific to the blades used throughout the test to determine the normalized cutting stroke lengths. Theoretically, this brings about comparable test results, also considering the manufacturing characteristics of the blade batch.

4) The resulting data pairs of normalized cutting stroke lengths and applied forces are marked on a scatter diagram.

5) We select the type of the first regression curve by a free choice and draw the curve that best fits the data pairs using the least squares method.

6) Based on the first regression curve, we obtain new measurement data applying a force value (which is the force calculated at 20 mm on the first curve), to improve statistical reliability.

7) Supplementing our data points with the newly measured values, we determine the compression force at 20 mm cutting stroke length, using the equation of a new (more precise) regression curve.

8) The performance level of the assessed protective equipment can be defined using this force value, according to the limit values prescribed in a table of the standard.

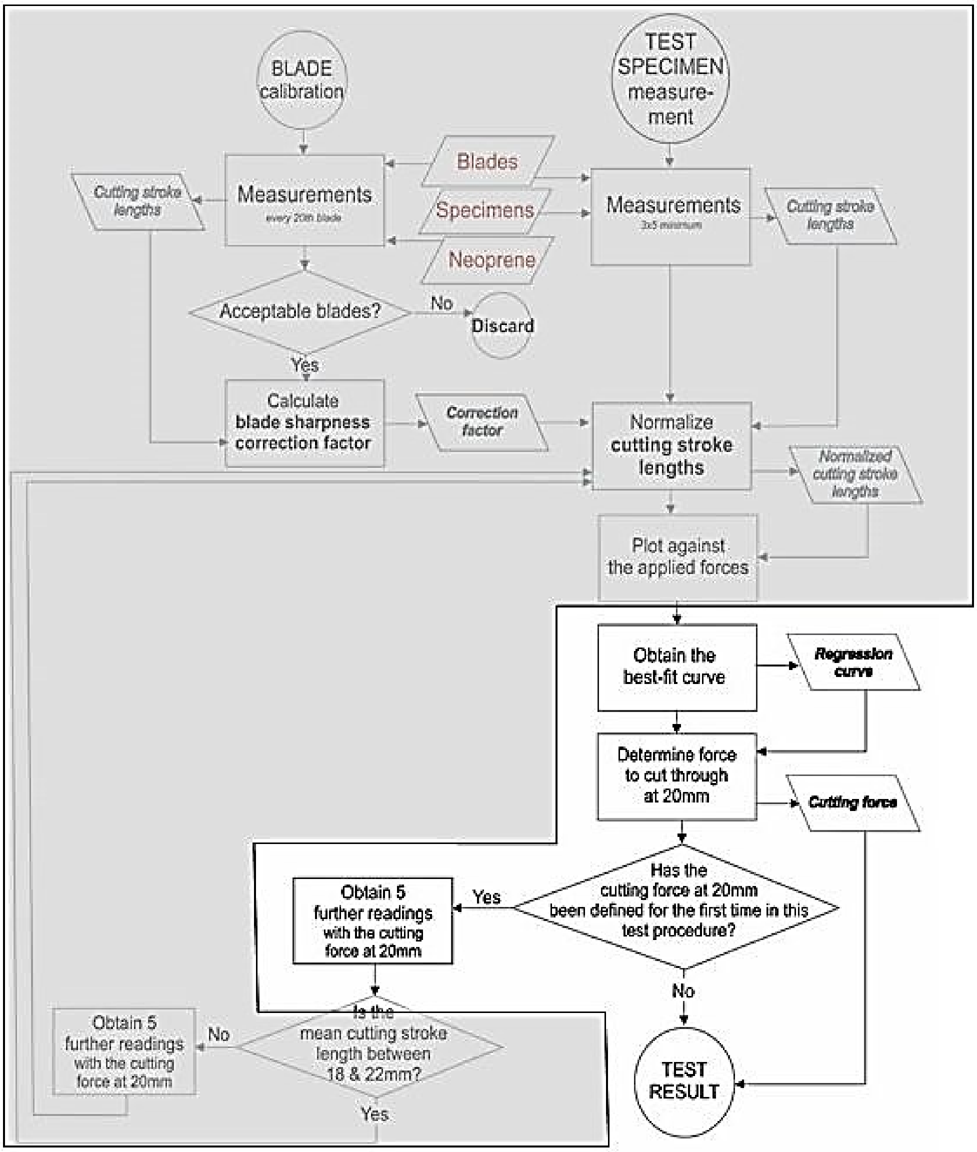

Figure 2: Test procedure according to ISO 13997:1999. The part targeted by this article is on white background [4]

MAIN ISSUES OF THE TEST METHOD

Measurement uncertainty as to the quality metric of the measurement

Basically, as the topic is about the development of measurement uncertainty as a parametrized quality characteristic resulting from the measurement procedure, it is necessary to redefine this metrological concept and the meaning of the numerical value. Measurement uncertainty is a *"parameter, associated with the result of a measurement that characterizes the dispersion of the quantitative values that could reasonably be attributed to the measurand"*[1] Due to the

[1] JCGM 200:2012 International vocabulary of metrology – Basic and general concepts and associated terms

different components and parameters of the measurement process, there may be several reasons for this dispersion or variation. These are contributions to uncertainty. (Contributions might be caused by the various and cumulating variations of the measuring instrument, operators, environmental conditions, measured object and test method.) [5]; [6]

Contributions to measurement uncertainty relating to the TDM test method [4]

The reasons of the significant variation of the measured values were analyzed in our previous research and the following causes were identified. The combined uncertainty value is the sum of the individual uncertainty factors, which are also required to be specified by the laboratory's quality management system. [7]

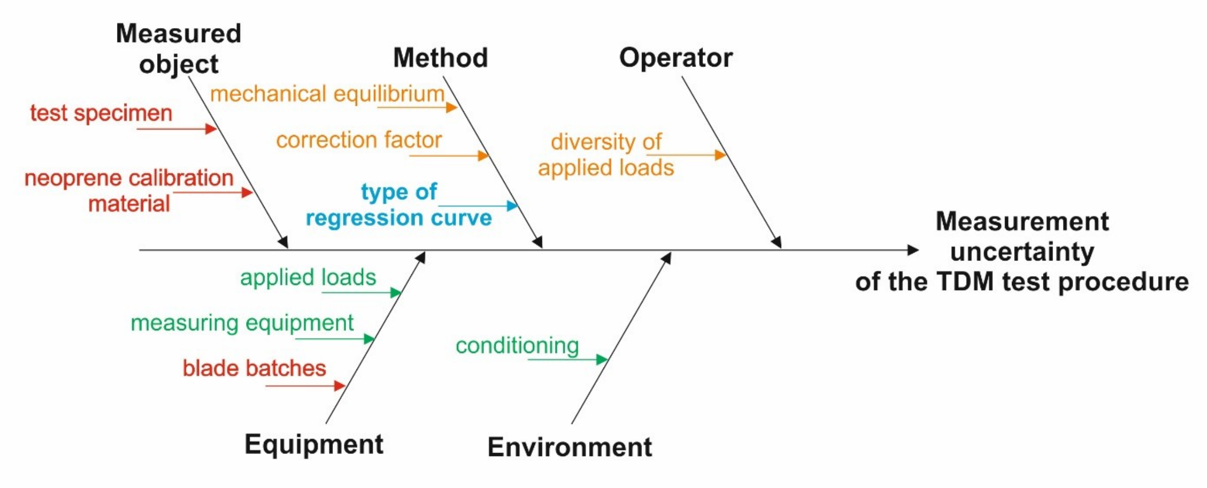

Figure 3: Known uncertainty factors of the TDM test method [4]

Based on experience, the components of uncertainty can be divided into four groups in case of this test method (Figure 3.):

- The factors that are limited by the regular, documented accuracy checks, calibrations and recertifications of the instruments are marked in green. These factors are undoubtedly taken care of in case of an accredited laboratory.
- The factors which (during present conditions and level of elaboration of the current standard) may cause even greater uncertainty values but can be eliminated with more exact test instructions are marked in orange. During this measurement procedure, these factors are caused by the slightly uncertain mechanical equilibrium of the equipment, the determination of the correction factors, and the diversity of the applied force. At present, these could only be separately quantified through extensive (and rather expensive) experiments. Nevertheless, their cumulated variation is included in the value of the combined uncertainty, using the previously developed method using the model of error propagation. [8]
- Factors that are significant and sources of uncertainty to be assessed, are marked in red. However, the exact value of these factors could also be determined by performing a significant amount of costly test procedures. Operating in accordance with applicable standards, it is assumed to be kept to a minimum.

- The factor marked in blue highly depends on the competence of the staff evaluating results and the test method itself. This is the subject of our present sub-research.

Final definition of measurement uncertainty

According to the requirements of the standard, the test result is not given by the directly measured cutting stroke lengths induced by the stable load force. Instead, the result is calculated indirectly from the equation of the regression curve of the data pairs representing load forces and cutting stroke lengths.

In the course of our previous research, we chose a practically costless method by using a model of error propagation (as described in *GUM - Guide to the Expression of Uncertainty in Measurement*) instead of directly measuring the factors of uncertainty and calculating their combined variance. Using this error propagation model, we estimate the value of "U" by the correlation between input and output values which can be used for indirect measurements, as well as by the determination of error propagation described in the function. The input value (x) is the operator-adjustable cutting force, whilst the output value (y) is the so-called *cutting stroke length,* expressing the distance traveled by the blade until the specimen is cut through. [8]

The regression curve and the uncertainty of the end result

The regression curve drawn between the measured data pairs includes the uncertainty of the cutting force (taken on the x-axis) which had been set. Without other options, this is estimated using the residual standard deviation of the associated cutting stroke length values (taken on the y-axis). When, according to the standard method, the force belonging to 20 mm is assigned, the assignment also comprises this variation (and therefore the extended uncertainty U). As a result, the error propagates to the value of the cutting force, which shall be calculated using the regression equation. [8]

Therefore, if we have defined the measurement uncertainty of the input characteristic (cutting stroke length) (u_r), and the slope of the curve (F'), we are also able to quantify the error applying to the output characteristic (cutting force) (u_{Fv}). (Figure 4)

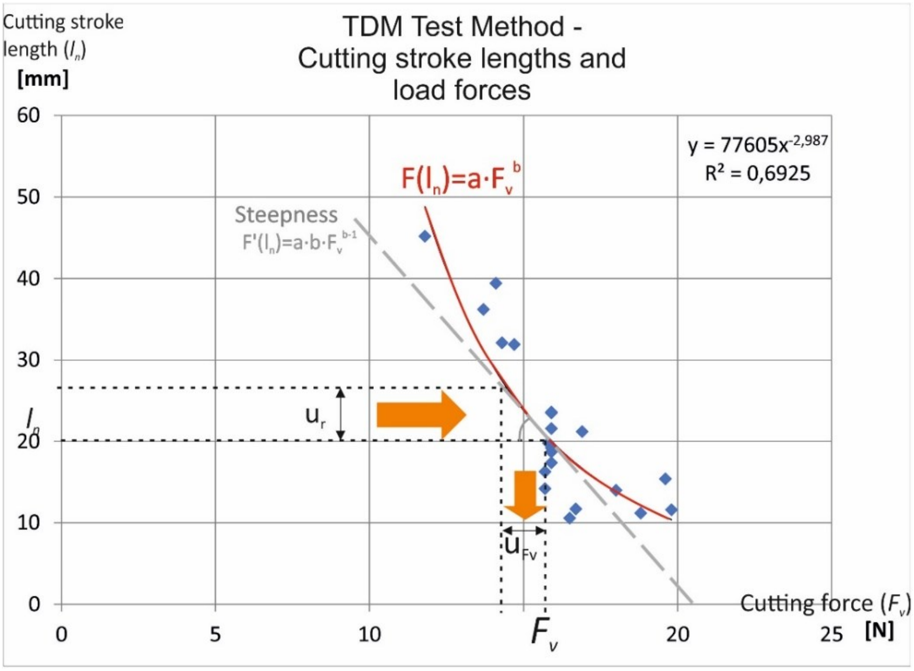

Figure 4: Propagation of error on a regression curve (example) [8]

Using the derivative of the function selected for the respective test procedure, the equation describing the slope of the curve shall be obtained, which is required to work with the error propagation model.

The final determination of uncertainty values is further complicated by the fact that another 5-10 additional confirmatory measurements shall be performed applying the load obtained as a partial result at 20 mm.

In our previous research, we had already elaborated that even the first (normalized) cutting stroke lengths (l_n) have their own uncertainty (u_{ln}), as a consequence of a random error in the determination of the correction factor. This paper does not count with these, as solely the curve selection's effect on the uncertainty is included in our current study. [8]

Adding the newly obtained confirmatory data points to the results mentioned above, the cutting force at 20 mm needs to be recalculated, using a second regression curve.

EXAMINATION OF THE UNCERTAINTIES CAUSED BY THE SELECTION OF REGRESSION CURVES

In consequence, the regression equation models the relationship between the load force and its resulting cutting stroke length. As seen on Figure 1. and in the steps of the method described below, the combined uncertainty factors consisting of the calculation and determination of the correction factor and the normalized cutting stroke length are not discussed in this paper, they are taken as a given and as a default value for subsequent analyzes. The aim of our research is a comparative analysis of the uncertainty values formed as a result of the free choice of regression curve type made by the evaluator during the test procedure.

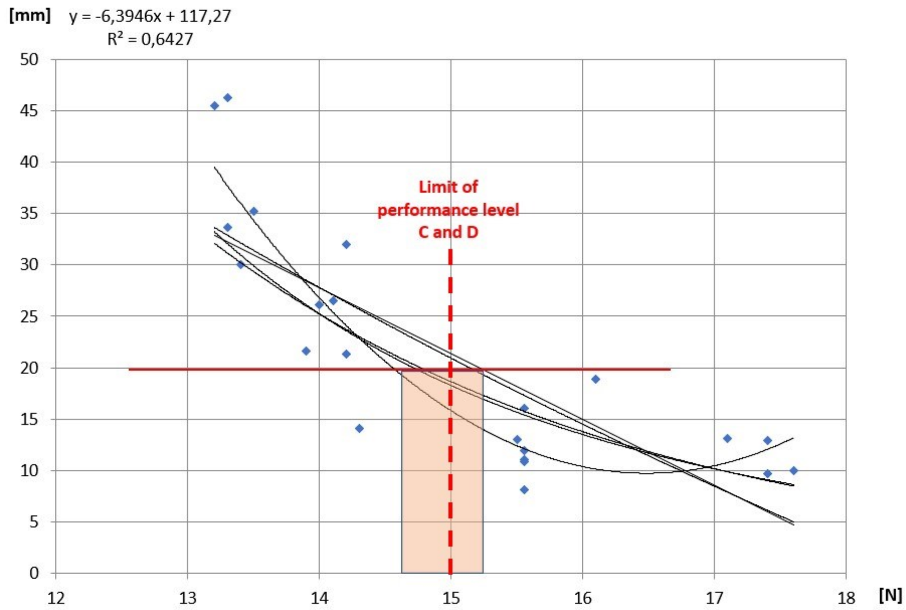

Figure 5: Differences in obtained cutting force values at a 20 mm cutting stroke length (curves of approximations with linear, quadratic polynomial, logarithmic, exponential and power functions) by selecting different regression curves for a typical TDM test result data set

According to our hypothesis, with the free selection of regression curve which is allowed by the standard, the final value of the measurement uncertainty and thus the risk of the performance level classification of the final product depends on the momentary decision of the person performing the analysis. (Figure 5)

In our research, we used two sets of test data, for which the preliminary calculations have already been performed until the first part of the process. The power function chosen according to the maximum of R^2 showed a relationship tightness of 0,8, while that of the other showed a significantly worse value around 0,4. These two patterns of variation do not count as extraordinary when performing real tests, even considering the similar material types. Figure 4 shows the two data sets and all possible trendline types (which is offered by MS Excel as a default setting) outlined on the same chart. It is obviously noticeable that 20 mmthe curves are characterized significantly differently. However, from the viewpoint of uncertainty and product classification, the focus will be on the uncertainty of the force values belonging to a cutting length of 20 mm.

The exact instruction of the test standard is the following: "obtain the best-fit regression curve" for the *applied force-cutting stroke length* data pairs. In practice, this would imply that the analyst would try all recommended types for the trendline during data entry and select the one with the highest R^2 value.

According to proficiency test results, there was no curve type which had been standing out significantly from the laboratories' chosen curves, in regard to the same material. Taking a look at one of the proficiency test reports, the types of approximation curves that may be selected by Excel were used with following distribution. (Figure 6) [9]

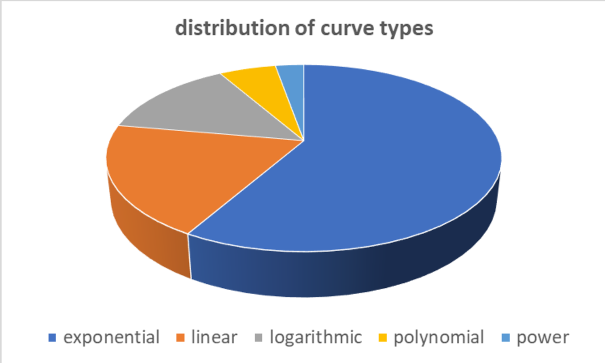

Figure 6: Distribution of the selected curves by type in tests involving nearly forty laboratories

According to laboratory experience and to the understanding of operators using the procedure (who do no use advanced statistical procedures at most), this is caused by a complex issue. [4] It might be partly true that the laboratory technicians performing the analysis are not explicitly proficient in this special mathematical-statistical procedure at the level of a researcher. Moreover, we considered all possibilities. According to this, it may happen that

- they choose a “proven” curve that most often shows a good fit,
- the first curve with a relatively high R^2 factor is chosen (an estimate of this limit is already relative),
- it might be a realistic situation– but not appropriate, naturally – that a curve type is accidentally included in the local standard operating procedure as a local standard, so it becomes a standardized “automatism” which is executed by staff complying with the rules
- it is not impossible that the best visual approximation indicator is selected without comparing R^2 values.
- Ultimately - and really only as a theoretical assumption, using a hypothesis alien to the ethical core values of an accredited laboratory - that the curve that intersects the 20 mm line at the highest force value, (in line with the goals of the customer at this single point which leaves freedom to the laboratory) would be secretly selected.

In our research, practical examples were analyzed for two selected data sets, such as

- the curve’s coefficient of determination adjusted to data points – $R^{2,}$,
- the value of the applied force at a cutting stroke length of 20 mm,
- the value of the applied force at a cutting stroke length of 20 mm, as the measurement uncertainty of the end result, and
- during the product certification process, how the risk of product classification based on the applied force varies depending on the curve choice.

A collection of the best and worst values of the four aspects for the distinct curve types are shown on the table below (Table 1.). The upper table shows a chart of a test procedure with a low relationship tightness and the lower one shows high relationship tightness. Although we cannot draw statistically correct and established conclusions from the number of charts analyzed, we can make the following conclusions - setting direction for future research.

The increase in the tightness of the relationship (R^2) presumably means that with a data set with less measurement uncertainty and a more informed curve choice, we can facilitate obtaining more beneficial results regarding safety considerations. The contrary is also true, as a poorly selected curve on a higher quality data set will show consistently worse results.

Table 1.: Example evaluations of real, weakly correlated and strongly correlated data sets for 1.) R^2 (the higher the better), 2.) cutting force (the higher the better), 3.) measurement uncertainty (the lower the better) and 4.) risk (the lower the better)

Type of Regression Curve		Power	Linear	Quadratic Polynomial	Logarithmic	Exponential
R^2 **(weak relationship)**	First curve	0,3668	0,4244	0,4599	0,4156	0,3755
	Second curve	0,2054	0,3669	0,2621	0,2168	0,2100
Result (F_{v2})		7,7782	8,1752	5,1550	8,2488	7,7989
Uncertainty of the end result (u_{Fv2})		0,8868	0,9507	0,6307	1,0779	0,6467
Level of performance achieved		Level B	Level B	Level B	Level B	Level B
Lower limit value (F_{min}) [N]		5	5	5	5	5
Risk of not reaching the lower limit value	z_i	-3,1328	-3,3398	-0,2457	-3,0140	-4,3279
	%	0,09%	0,04%	40,30%	0,13%	0,00%

Type of Regression Curve		Power	Linear	Quadratic Polynomial	Logarithmic	Exponential
R^2 **(tight relationship)**	First curve	0,7687	0,6723	0,7945	0,6965	0,7446
	Second curve	0,6799	0,6427	0,7499	0,6225	0,6669
Result (F_{v2})		10,7167	11,7114	10,6815	11,3363	10,8027
Uncertainty of the end result (u_{Fv2})		1,1436	1,2052	0,3565	1,0150	0,4225
Level of performance achieved		Level C	Level C	Level C	Level C	Level C
Lower limit value (F_{min}) [N]		10	10	10	10	10
Risk of not reaching the lower limit value	z_i	-0,6267	-1,4200	-1,9118	-1,3166	-1,8996
	%	26,54%	7,78%	2,80%	9,40%	2,87%

Best value   Worst value

RISK OF CURVE SELECTION AND SAFETY CLASSIFICATION

Essentially, the final aim and output of the entire TDM test procedure is a categorization according to the the level to which the product used as personal protective equipment provides protection against cutting by sharp objects. Classification is based on the value of the force required to realize a cutting length of 20 mm on the product.

As the measurements have a certain amount of uncertainty, the actual value of the declared cutting force for a product also has a variation according to normal distribution (with parameters F_v; u_{Fv}), where the expected value equals the cutting force, and standard deviation is represented by the standard uncertainty of the measurement. [8] Therefore, the actual protective performance of the product is also expected to be above or below a specified limit value, according to a calculable probability. This probability can essentially be translated as a risk of an accident. Next to the category limits (Figure 7.) we can place the appearance of the uncertainty of a measurement result and the probability density function parametrized by (F_v; u_{Fv}).

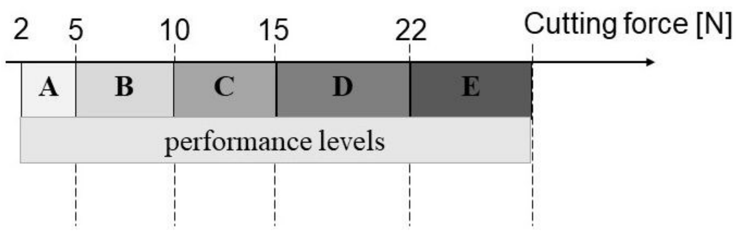

Figure 7: Cutting force categories and their limit values

As the measurements have a certain amount of uncertainty, the actual value of the declared cutting force for a product also has a variation according to normal distribution (with parameters F_V; u_{FV}), where the expected value equals the cutting force, and standard deviation is represented by the standard uncertainty of the measurement. Therefore, the actual protective performance of the product is also expected to be above or below a specified limit value, according to a calculable probability. This probability can essentially be translated as a risk of an accident. Next to the category limits we can place the appearance of the uncertainty of a measurement result and the probability density function parametrized by (F_V; u_{FV}). [3]

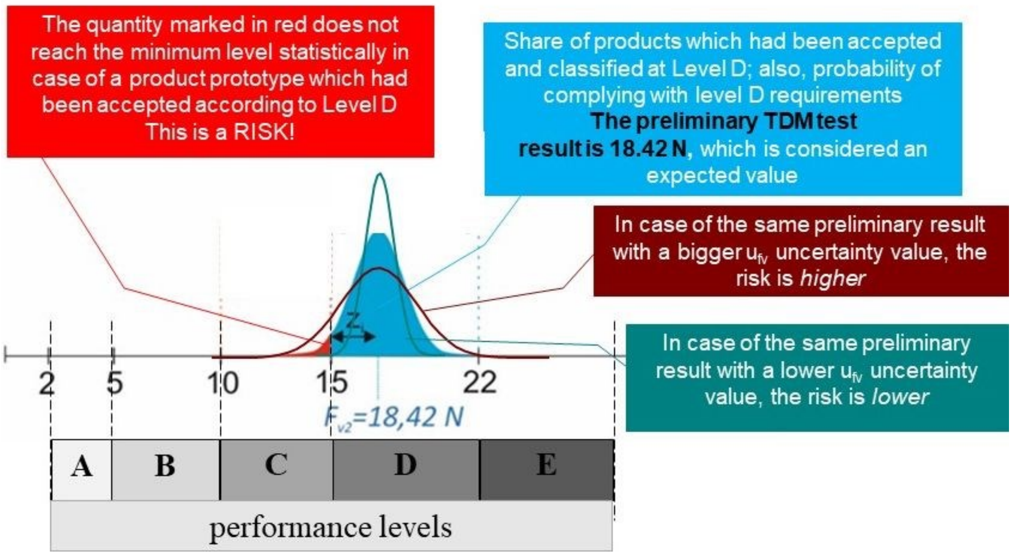

Figure 8: Understanding the risk of classification [3]

In the table seen in (Figure 8), for the low- and highly correlated test, the *performance level* and the *probability of non-compliance with the lower limit* of the category, as well as the *value of the risk of accident* identified with the *probability*, are also indicated for the summarized data.

Due to the small number of our tests which were carried out on the effects of regression curve selection, we do not make any assumptions about the presupposition or exclusion of any of the appropriate curve types. The extent of the intersection of regression curves at 20 mm. Based on the data series, we dare to make an estimate that the x-direction extent of the intersection points resulting from more accurate (showing a higher R^2) and more inaccurate (showing a lower R^2) curves is not necessarily related to the tightness of the relationship. It also appears that more advantageous uncertainty values of more accurate curves may modify the classification with a well-chosen type of regression toward lower risk.

Moreover, in addition to finding the best fit curve as required by the standard, it would be useful to take into account the uncertainty of the end result (which is obtained using the curves) or the level of risk associated with the lower limit of the category.

CONCLUSION

Despite the fact that accredited laboratories are following the standard's measurement procedure as precisely as it is possible, their choice of regression curve type is subject to different practices. This may result in a greater risk regarding classification according to the level of protective capability when combined with a certain degree of uncertainty in respect of the cutting force. We were drawn to the conclusion using real measurement data sets that a high correlation value is not necessarily associated with less measurement uncertainty as well as less classification risk.

Table 2.: Letters marking the model of error propagation of the TDM test method

Letter	Definition
l_n	normalized cutting stroke length on the test specimen
u_{ln1}	uncertainty of the determination of the normalized cutting stroke length
u_{r1}	combined uncertainty of the first regression curve
u_{Fv1}	uncertainty of the firstly determined cutting force
F_{v1}	applied load force calculated using the first curve
F_{v2}	applied load force calculated using the second curve (the end result)

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COLOR MEASUREMENT OF SAMPLES WITH SURFACE STRUCTURE USING DIRECTIONAL AND DIFFUSE GEOMETRIES

Ákos BORBÉLY

Abstract: *Surface structure has a fundamental influence on the visual appearance of the color. Two identical colors may become very different if their surface properties are changed by coating or other finishing methods. Variations in the spatial distribution of the reflected light are a challenge when choosing the appropriate instrumentation for the color measurement of products. There are standard arrangements for enhancing or for diminishing the effect of surface patterns in the obtained data. Sphere instrumentation is often used to homogenize the variations caused by surface structure, directional geometries can have ring illumination or collection for the same purpose. In this study standard, CIE measurement geometries are tested on color scales with different surface patterns. Two instruments were chosen with diffuse and directional geometries and the obtained colorimetric data are evaluated.*

Keywords: *CIE measurement geometries, surface pattern*

INTRODUCTION

Accurate color reproduction is highly important in the graphic arts industry. Standardized color management offers a practical solution but working with a wide range of instruments with different measurement setups can be challenging, and often results in inconsistent measurement data for the same sample.

Quantifying color starts with obtaining tristimulus values of object colors, but there are also 3 critical measurement parameters that will have a major influence in determining the colorimetric values.

Illuminant

The illuminant is a dominant factor in the calculation of the tristimulus values. In the case of non-self-luminous objects, instruments obtain the spectral reflectance factor of the surface of the sample, which needs to be multiplied by the relative spectral power distribution of the illumination in order to obtain a color stimulus. There is a wide choice of CIE standard illuminants for this purpose: illuminant A representing incandescent lamps, the illuminant F series representing fluorescent lamps, and the daylight illuminants simulating daylight spectrum which varies during the day, the seasons, etc. Standard illuminant D65 represents average daylight and is recommended by the CIE to be used in colorimetric computations unless the application or the simulated viewing situation requires another specific or standard illuminant.

Colorimetric observer

The standard observer is used for the calculation of the tristimulus values. The CIE 1931 2° standard observer is recommended for small (1°-4°) viewing fields. For larger viewing fields the CIE 1964 10° standard observer is to be used, which should be noted by a 10 in the subscript (eg. X_{10}).

Measuring geometry

The measuring geometry is simulating the viewing situation of the visual evaluation. The directions of illumination and viewing will determine the visual appearance of the color. The geometry of the illumination of the sample and the collection of the reflected light will affect the recorded reflectance spectrum. The comparison of measurement results obtained by different instruments is logical only if they implement measurement geometries that are standardized. For this purpose, the CIE standardized two groups of illumination and detection: directional and diffuse.

Directional illumination and directional collection

In forty-five degree directional geometries generally the sample is irradiated under 45 degrees to the surface normal of the sample. If the illumination comes at one specific azimuth represented by direction x the notation is 45°x:0° (figure 1).

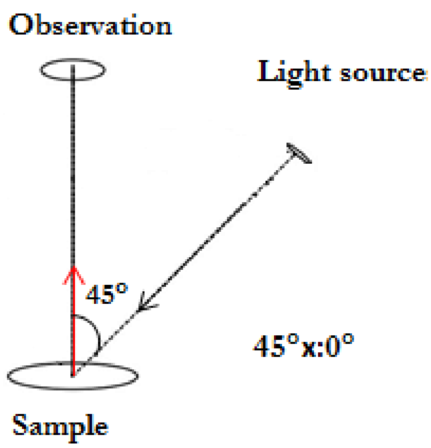

Figure 1: Directional geometry 45°x:0°

The usually unwanted effect of this geometry is, that in the case of a surface structure the measured value will depend on direction x. Readings will be more stable for samples with surface pattern if a ring-shaped illumination is applied. The notation of the 45-degree annular geometry is 45°a:0° (figure 2).

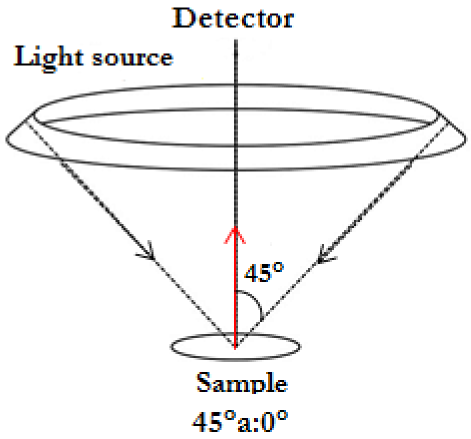

Figure 2: Directional geometry 45°a:0°

The annular geometry can be approximated by placing light sources in a ring or a similar optical arrangement. This case is called a circumferential geometry, the notation is 45°c:0° (figure 3).

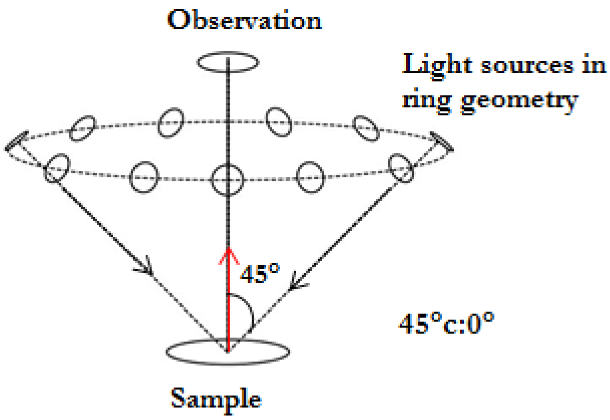

Figure 3: Directional geometry 45°c:0°

In a normal to forty-five degree directional geometry the light path is reversed; illumination comes in the line of the surface normal, the reflected radiation is collected at 45 degrees to the surface normal at one azimuth angle (0°:45°x) or in a ring optics (0°:45°a, figure 4).

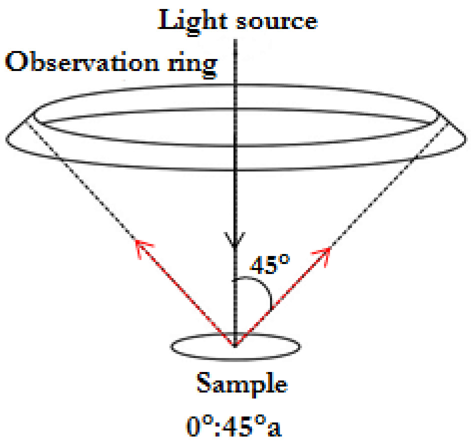

Figure 4: Directional geometry 0°:45°a

Diffuse illumination and direct collection

Diffuse illumination or collection is implemented by an integrating sphere. The sphere wall is covered with a highly reflective (more than 98%) diffuse white coating with a flat spectral response to homogenize light from the source of the sample by multiple internal reflections. Baffles are placed in the sphere to prevent direct light paths to the sample or to the measurement port. Illumination is positioned 8 degrees from the surface normal of the sample. In this setup the regularly reflected light is included in the measurement, the notation is di:8°. If a gloss trap is applied in the direction of the specular reflection (specular reflection excluded) the notation becomes de:8° (figure 5).

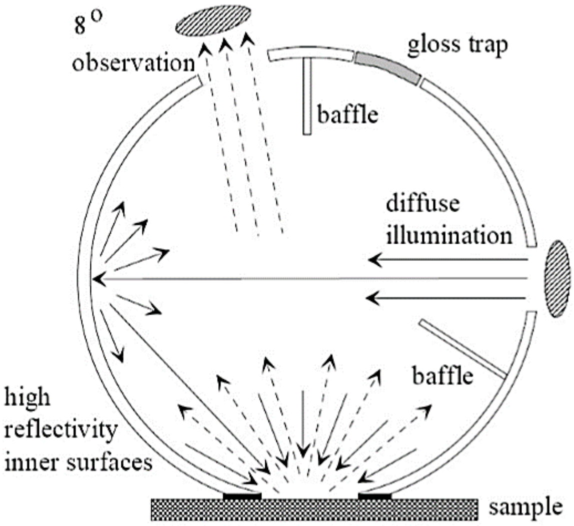

Figure 5: Measurement geometry de:8°

Directional illumination and diffuse collection

The reverse of the previous optical arrangement can also be applied. Depending on the inclusion or exclusion of the specularly reflected component the notation is d8°:di or 8°:de (figure 6).

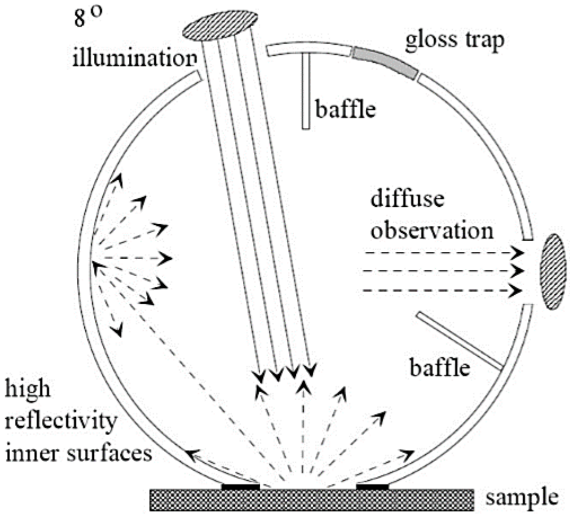

Figure 6: Measurement geometry de:8°

Further measurement parameters (eg. the optical properties of the backing of the sample in case of non-opaque specimens, etc.) can also significantly affect the obtained colorimetric values [1][2][3].

Measurement conditions for fluorescent samples

In the past decades, the usage of optical brightening agents became widespread in the production of substrates applied in the graphic arts industry. As brightness is a key attribute of papers, it is hard to find a contemporary printing paper that lacks an optical brightener as a component.

The presence of fluorescent material in the sample may result in inconsistent measurement data. In order to preserve color consistency in industrial workflows, new measurement standards were published by the ISO for measurement conditions suitable for applications for substrates containing optical brighteners.

In the corresponding standard (Spectral Measurement and Colorimetric Computation for Graphic Arts Images ISO 13655:2009, ISO 13655:2017) four-color measurement modes are specified [4]. These modes were developed for "fine-tuning" the color measurement conditions regarding fluorescence:

M0: in this measurement mode gas-filled incandescent lamp is to be used, the spectrum of which has a good agreement with CIE standard illuminant A (correlated color temperature: 2856K). Incandescent lamps have typically low power in the near-UV spectral range, which may cause complications when optical brighteners are present, as the effect of the fluorescence is dependent on the amount of radiation in this range. The standard uses the term „legacy" to indicate that most instruments introduced prior to the standard may be kept in service and provide valuable data. Because of the widespread use of optical brighteners this mode can be considered obsolete in the graphic arts industry.

M1: this measurement mode is developed for fluorescent samples making it the preferred mode over M0 for the print industry. Therefore the light source spectrum has to have a strong near-UV content corresponding to the CIE standard daylight illuminant D50.

M2: in this measurement mode a UV filter is applied in order to exclude the UV content of the illumination.

M3: in this measurement mode a polarization filter is applied. The UV filtering condition also holds, just like in the M2 mode. The objective of the application of polarization is to remove or minimize surface reflection. This condition may be desired when making predictions for a dried print based on measurements on a wet print, which exhibits significantly more gloss.

EXPERIMENTAL

In this experiment, two devices are used to obtain colorimetric data of samples with various surface structures. The configuration of both instruments allowed for the measurement of spectral reflectance factor and comply with M0 Mode of ISO 13655:2017 (table 1).

Table 1: Instrument specifications

Instrument	Xrite eXact spectrophotometer	Avantes AvaSpec-3648 Fiber Optic Spectrometer
Measurement geometry	45°a/0°	de:8°
Measurement mode	M0	M0
Light source	incandescent + UV LED	Incandescent halogen
Aperture	6mm	10mm
Integrating sphere	-	AvaSphere-50
short term repeatablility – white	0.05ΔE*ab (manufacturer data)	0.15ΔE*ab (measured)

For the calculation of tristimulus values, the 2° standard observer was chosen together with D65 standard illuminant. The component of the Avantes bundle was connected by FC-UVIR400 cables with 400 μm fiber. According to manufacturer data the integrating sphere reflectance factor was above 98%, with a flat (approximately wavelength-independent) response.

The samples were opaque and chosen from a larger collection, each set with the same matte colors but different embossed textures. Eight colors were chosen (figure 7.) to represent all four quadrants of the a*, b* chromaticity plane of the CIELAB color space at reasonable chroma (except for the achromatic). The dimensions of the individual samples as seen on the color strip was 10cm x 1cm.

Figure 7: Set of color samples with texture #2

Four types of surfaces took part in this series of measurements. Close-up images of the surface pattern of the sample sets are shown in figures 8-11.

Figure 8: Close-up image of texture #1

Figure 9: Close-up image of texture #2

Figure 10: Close-up image of texture #3

Figure 11: Close-up image of texture #4

RESULTS

In this part of the study colorimetric values obtained by the two instruments are shown and compared to each other by the regular metrics. However it has to be emphasized that the instruments simulate different viewing conditions, and “see” the same sample as different color stimuli. Therefore the difference values are representing amplitudes but have negligible visual meaning. Similarly, as the textures modify the appearance by affecting the optical properties of the surface, samples with the same hue of the scale look alike but are not identical.

The eight-color samples were measured on all 4 textured scales with both instruments. The*, b* values are shown for two of the textures in figures 12-13.

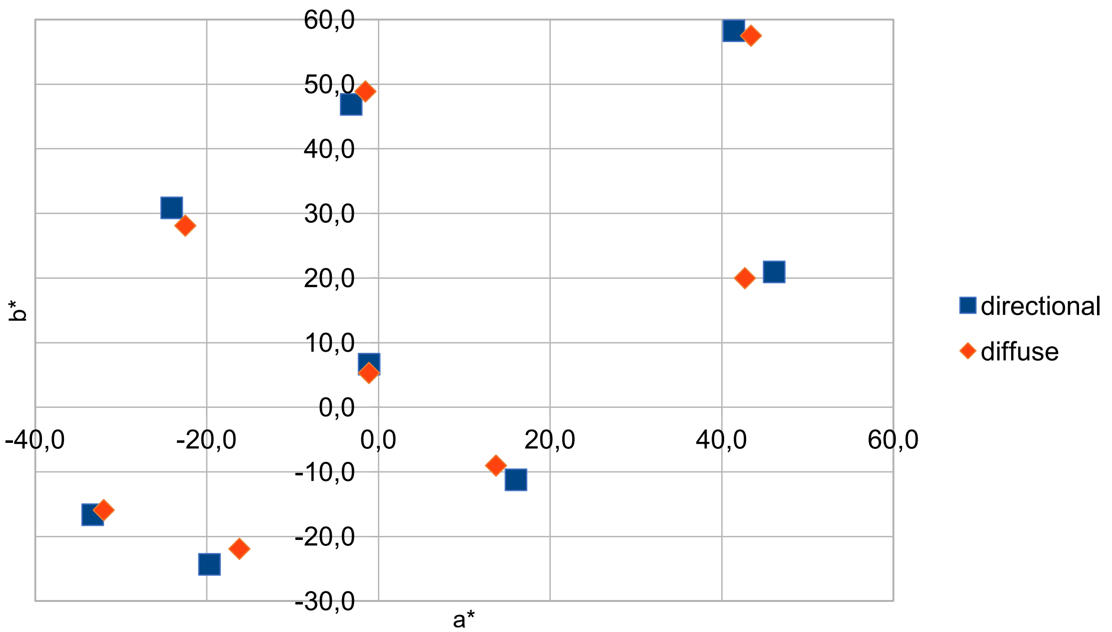

Figure 12: CIELAB a, b* values of the eight color samples with texture #1on the chromaticity plane, obtained by instrument with directional (blue squares) and diffuse (orange diamonds) measurement geometry*

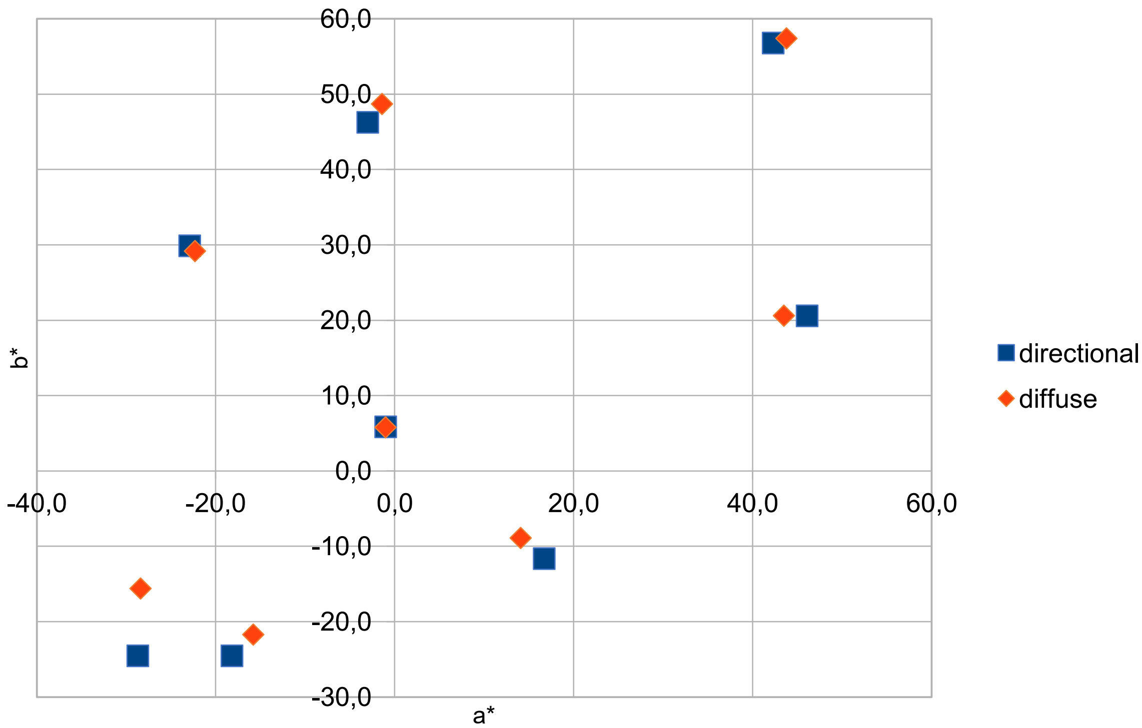

Figure 13: CIELAB a, b* values of the eight color samples with texture #4 on the chromaticity plane, obtained by instrument with directional (blue squares) and diffuse (orange diamonds) measurement geometry*

Color difference values (ΔE^*_{ab}) were also calculated between the data obtained by the two instruments together with the components of the vector: lightness difference (ΔL^*), chroma difference (ΔC^*) and hue difference (ΔH^*). These values are shown below in tables 2-5.

Table 2: CIELAB color difference (ΔE^*_{ab}) and its components: lightness difference (ΔL^*), chroma difference (ΔC^*) and hue difference (ΔH^*) between values measured by instruments with directional and diffuse geometry on color samples with surface texture #1

Texture #1	ΔE*ab	ΔL*	ΔC*	ΔH*
Red	4,3	2,5	3,5	0,5
Orange	3,5	2,8	0,5	2,1
Yellow	4,2	3,3	1,9	1,8
Green	5,9	4,9	3,2	0,5
Light blue	5,9	5,7	1,5	0,0
Blue	6,0	4,2	4,0	1,3
Violet	3,8	2,1	3,1	0,5
Grey	5,1	4,9	1,4	0,3
All	38,7	30,4	19,2	7,0

Table 3: CIELAB color difference (ΔE^*_{ab}) and its components: lightness difference (ΔL^*), chroma difference (ΔC^*) and hue difference (ΔH^*) between values measured by instruments with directional and diffuse geometry on color samples with surface texture #2

Texture #2	ΔE*ab	ΔL*	ΔC*	ΔH*
Red	5,5	2,0	4,8	1,9
Orange	4,7	4,4	0,8	1,4
Yellow	5,6	5,3	0,6	1,5
Green	6,9	5,7	4,0	0,2
Light blue	6,9	6,6	1,9	0,3
Blue	6,2	4,9	3,7	0,9
Violet	4,8	0,5	4,7	1,0
Grey	5,0	5,0	0,2	0,1
All	45,6	34,4	20,6	7,3

Table 4: CIELAB color difference (ΔE^*_{ab}) and its components: lightness difference (ΔL^*), chroma difference (ΔC^*) and hue difference (ΔH^*) between values measured by instruments with directional and diffuse geometry on color samples with surface texture #3

Texture #3	ΔE*ab	ΔL*	ΔC*	ΔH*
Red	6,1	2,8	5,3	0,9
Orange	5,0	4,7	0,3	1,8
Yellow	5,4	4,2	2,7	1,9
Green	6,4	5,5	3,3	0,4
Light blue	5,9	5,6	1,8	0,2
Blue	5,4	3,4	4,1	0,6
Violet	5,8	0,5	5,7	1,3
Grey	4,4	4,4	0,3	0,1
All	44,4	31,1	23,5	7,2

Table 5: CIELAB color difference (ΔE^*_{ab}) and its components: lightness difference (ΔL^*), chroma difference (ΔC^*) and hue difference (ΔH^*) between values measured by instruments with directional and diffuse geometry on color samples with surface texture #4

Texture #4	ΔE*ab	ΔL*	ΔC*	ΔH*
Red	4,7	3,9	2,4	1,1
Orange	4,2	3,9	1,4	0,8
Yellow	5,7	4,9	2,3	1,7
Green	7,6	7,5	0,9	0,1
Light blue	7,2	7,1	0,8	0,8
Blue	6,5	5,4	3,7	0,3
Violet	4,8	3,0	3,7	0,8
Grey	5,4	5,4	0,1	0,0
All	46,1	41,1	15,2	5,6

Table values confirm that the two instruments measure significantly different color stimuli due to the dissimilar spatial distribution of light in the optical arrangements. The amplitude of the difference between the readings of the two instruments imply that the visual difference is well above the threshold level in every case. In general the largest difference is in lightness, followed by chroma, and the hue difference is the smallest.

CONCLUSION

International standards specify numerous parameters regarding the optical set-up of the instruments for manufacturers. This variety serves the manifold objectives in colorimetric practice. Sometimes the purpose is to eliminate the effect of surface structure. Diffuse geometries meet this purpose, but are discouraged in the graphic arts industry where optical brighteners are often present, and thus directional geometry is preferred. In this study instruments with diffuse and directional geometries were used for the measurement of non-fluorescent samples with surface texture. Four types of textures were chosen with the same set of colors. Results have shown a large disagreement between the two instruments, typically 4-7 ΔE^*_{ab} color differences were found. The highest deviation was in lightness, the chroma difference was lower, and the hue difference was around or below threshold level in most cases.

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CHAPTERS FROM THE HISTORY OF HUNGARIAN ELECTROGRAPHIC ART

Judit ALBERT, Csilla KELECSÉNYI

Abstract: *Art and digital technology crosses each other's paths in innumerable ways and cover a vast area of human culture; thus, they in themselves deserve a philosophical analysis. Furthermore, theorizing about the relationship between art and digital technology is by no means an easy task because even the debates about art in the last millennia are not over. At the same time, among many other phenomena, new levels of computers and their artistic use have entered the range of issues to be explored. Examining the history of the Hungarian avant-garde movement, the complex connections between digital media and contemporary art are revealed. In the background of the art of the 1960s, the rise of digital technologies can be compared to the rise of the media. Reviewing the history of Hungarian digital art, the real roots of the art trends of the time can be explored and understood, which I hope will encourage today's artists to unleash their experimental creativity.*

Keywords: *digital art, contemporary art, electrographic art*

INTRODUCTION

Development engineers and programmers created the first digital works of art. Since the 1970s, but especially in the 1990s, the most innovative artists have systematically adapted technological processes with a common technical basis for reproduction and its process. Huge technological advances and opportunities in graphics and design have opened up new perspectives for capturing and manipulating images. With this came the time for the interaction of technologies that had been linked from the outset: electrography and computers. Béla Julesz developed the random-point stereogram in 1959, where image pairs of computer-generated random points create the illusion of a three-dimensional image under a stereoscope. Vera Molnar is also one of the earliest pioneers in computer art, although she created her first generative knife series without a computer. Electronic graphics, polaroid photographs, video graphics, photograms, creative photocopies, electronic publications were born. All of these form an extensive creative panorama of the spaces for artistic creation, and their common technical origin is that they are all electrographic. Their impact on contemporary art is as important as the philosophical illumination of their essence and meaning, their exploration of their artistic and technological significance, and not only for ordinary people but also for art professionals and critics.

Despite the fact that many critics have dealt with this topic in a specialized way since the 1960s, none of them has managed to transcend the conceptual limits of the international circle of professionals and contemporary critics. On the other hand, computer graphics are often criticized by traditional artists "because it looks like"would have been made with a computer. It's like they're criticizing ceramics because they look like they're made of clay. Nowadays, the same argument can be made for computer software, when the constant introduction of new products and developments makes it impossible for individuals to learn some of them. In contrast, the influx of technology — particularly affecting artists inspired by the medium itself — gives the impression that a computer artist can be a “device-driven” creator in traditional art worlds. An artist working with a computer must consider issues to which art historians, theorists, and aesthetics pay little critical attention. The most important questions are about the chameleon-like nature of computer art. Moving from technique and technology to mere content, we return to the traditional question of “what is art?" when we are in front of or immersed in a work of art. If we are in front of a computer-generated work, it is worth unfolding the question, is this digital art? ", " is it based on an artistic idea? " or " is digital technology necessary for its existence? ". It cannot be said that this separation is possible in all cases, since often, if not always, we must also take into account the historical and cultural contexts surrounding the works analyzed: "what is the artist trying to express?" In 2016, an Amsterdam branch of an advertising company worked with Microsoft to develop a neural network-based system to create a new work: a painting in the style of Rembrandt, a Dutch master. [1] The question rightly arises: what is the message we should take home from these works? Does it happen? Perhaps it is to admire the technology that has made these results possible. There is a risk that this kind of endeavor will be detrimental to digital art, which will distract from the real, significant support that digital technology can provide to contemporary artists.

TECHNOLOGICAL PROCESSES IN ART

At the time of the emergence of photography, the rift between perceptual and conceptual theories began: the model of painting so far, as an independent form for the complete depiction of the appearance of nature, was the pictorial tradition. An infinite number of possibilities and processes have been revealed - which have been shaping people's attitudes and worlds ever since - at the moment of preparing for the automation of perception with the innovation of artificial vision by delegating the assessment of objective reality to the machine. Perhaps the most significant evolution in 1980 was the advent of laser copiers, that is, the use of laser beam technology, which allowed electrical signals to be converted back to light and then directed to an intermediate surface and a copy to be made by the usual process. Digital technology and the ability to split a color copy into four colors with color copiers increased the ability to play creatively as many image and color modification features became available, allowing them to be used to their full potential, which was hitherto sporadic in design, reproduction graphics, and in the field of printing. The unique computing tools now available to artists, such as image processing, visualization, simulation, and network communication, are tools for change, movement, and transformation, not capture. From the prototype used by Joseph Kadar to the generative systems created by the most advanced technologies, electrography explores this potential field from its parameters, affecting all image interpretation problems in contemporary culture. As for the strict analogy between knowledge and skills, the task of grasping representation includes the ability to see something hidden that is still available.

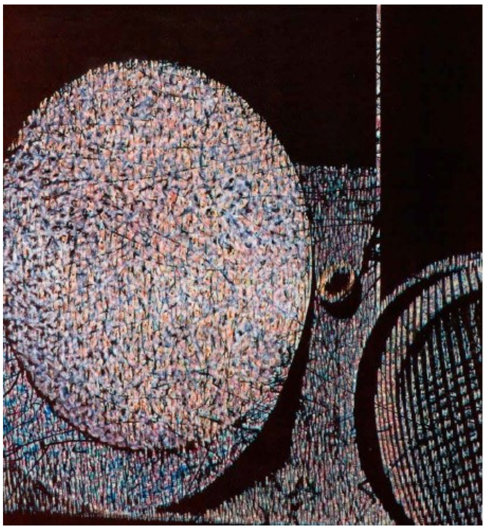

Figure 1: Kádár Joseph, Le Dualisme, xerox art 1989.

According to Polanyi, this should be seen in the context of an attempt by a skilled person to solve problems. [2] As Kelecsényi, who has been dealing with electrography since 2000, and more seriously since 2010, explains: “I mainly take photo-based electrography. I often use a found photo or my handmade work to generate a new pictorial world. I also create digital designs for my paintings, textiles or collages, as a supporting process in finding and selecting the optimal solution. In this way, I supplement and combine creative thinking with the possibilities provided by computer technology. Hand-made creations are still my main occupation, but I use the computer pre-design process. My independent digital works have a repercussion on my paintings, embroidery and paperwork, so the two techniques interact with each other during my work, and a digital overview of my old work also inspires me to create new works.”[3]

Figure 2: Csilla Kelecsényi, Our memories that we carried with us, textile collage, machine embroidery, 2015.

Xerography as an expressive technique

Xerography is derived from the Greek words xeros (= dry) and graphene (= writing), meaning a direct photocopy of an object or image. Differences in light intensity**, image media, and paper quality** can cause a difference between the work to be copied and the finished work. The general way to use works created with a photocopier is based on graphic results, which can be obtained by exaggerating **minor** errors in dark areas of the printout. Ágnes H**A**ász also created his electrographic works with a Xerox copier from the beginning, in whose works the process imaging layers are made up of single and serial variations.

Figure 3: Ágnes HAász, The Age of Anxiety, giclée print, 2001

Evelin Sós creates a poetic synthesis of photo – letter – object – fragment of text – music in her works: she leads the viewer to marginal landscapes. It reveals playful and imaginative forms to our eyes while asking, answering, arguing, that is, communicating in the language of visuality, introducing the viewer to the mystery of everyday life. From photocopiers to graphics software, Péter Herendi also uses various tools; for him, the essence of the creative process is finding a complete vision. **[4]**

Figure 4: Evelin Sós, After the Ice Dance, xerox art, 2002.

Electrographic art as a reference point

The concept of electrographic art as a reference point presupposes the development of a wide range of relative tools, thanks to the operational plus, to which other processes, factors, or intermediaries contribute. We include creative activities that view photocopying as a sketch, reference image, or just an element in another method in which photocopying is only one part of a broader concept. In this way, Ede Hallbauer's self-copying technique is also complex, including photography, graphics, experimental film, painting, auto-therapy, diary, and ars poetica. In Beaty Czető's works, the flashing body images also float into blurry layers of dimensions.

Figure 5: Ede Hallbauer, Self-Exploration, 40., offset print, 1992

Figure 6: Czető Beaty, Identity, c-print, 2007

According to Csízy, the essential functions already well-proven in the world of technology and science represent systems of proportions that are deeply embedded in our instinctive consciousness through our daily experience. These systems of proportions are well utilized in the visual arts. László Csízy experimented with computers from the mid-1970s when he created his earliest works.[5]

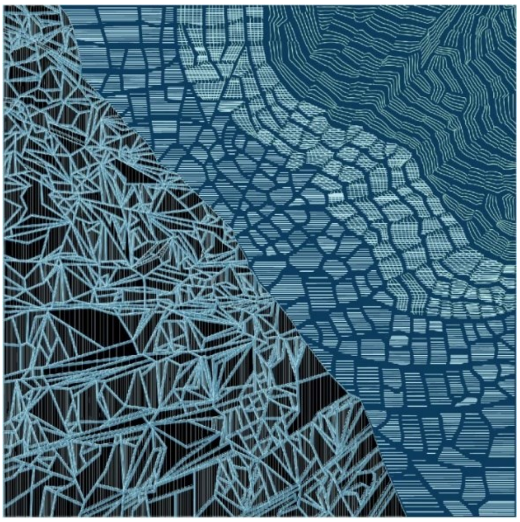

Figure 7: László Csízy: Rules, Computer Graphics, 2020

The majority of jr. Károly Koffán 's works are made up of illustrations and computer graphics created with 3D modeling. Edit Sándor brings invisible movements and processes to life digitally with the expansive possibilities of the electronic workflow.[6]

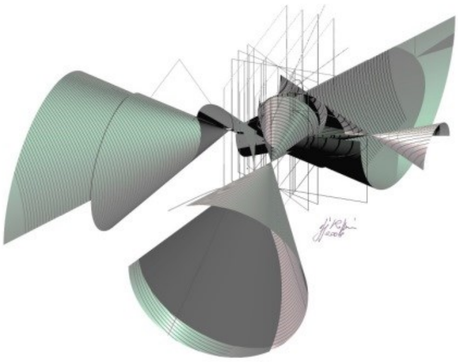

Figure 8: jr. Károly Koffán: Design 1., Computer Graphics, 2008

Art publications and art movement in Hungarian electrographic art

Some of the concepts often used for electrographic art, such as copy, media signal, witness communication, are closely related to historically conceptual and ideological positions. The first "rose action," a happening and a series of actions entitled "Artificial Respiration" were held at the Rózsa Presszó, Budapest, on March 7, 1976, its participants included Orsolya Drozdik and Zsigmond Károlyi, whose photographic works and exhibitions the use of xerox copies of text played an important role. The contemporary activities of György Galántai, who has been using the photocopying technique regularly since 1979 in the Artpool Art Research Center he founded, deserve special attention. In 1981, Artpool organized the first Hungarian mail-art exhibition. On the floor of the exhibition space, there were xerox copies of the Hungarian avant-garde from the ‘70s, and artistic postcards, mail-art works were presented in foil strips hanging in the space, and Róbert Šwierkiewicz's pages of the assembly of George's "Textile without Textile". It should be noted here that a modern version of mail art, e-mail art, has also been released. Tibor Vass has been publishing a new call every year since 2001, and the Arnolfini Archive launched its international e-mail project in 2004.[7] In May 1962, the avant-garde literary, critical and artistic magazine Magyar Műhely was published in Paris, founded by young artists forced to the West after 1956 - Pál Nagy, Tibor Papp - but also by writers living in Hungary from the very beginning.[8] The Hungarian Electrographic Art Association has primarily formed by the artists of the group the Shadow weavers with 19 founding members on August 17, 2001, in the Bartók 32 Gallery in Budapest.

MUTATIONS IN 21ST CENTURY ART COMMUNICATION

Today, we can see a real revolution in computing, not just on a commercial or technological level, but above all on a social level. Collaborative processes are ubiquitous in our society. In the field of communication, digital networks have facilitated collaborative activities, especially the phenomenon of virtual communities and social networks. Today’s field of work is strongly characterized by the production and exchange of knowledge, communication, and, above all, effective "investment,” where we find a strong need for collaborative networks, including virtual connections between artists around the world. Thinking in the distance, in real-time, in physical space has thus become obsolete. The developments of new technologies, and their inevitable manifestations in the field of art, suggest that we must constantly rethink our conception of reality, its physical and virtual concepts, its boundaries, and its certainties. It is precisely this wide-ranging capacity that secures the future of electrographic art, which we suspect will inevitably move forward. At the same time, it noticeably increases the potential tools that can be used in the creative work of artists.

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THE WAY OF ART FROM TEXTILE TO PAINTING

Csilla KELECSÉNYI

Abstract: *One of the essential groundbreaking artists of the renewal of textile art over the last half century was Margit Szilvitzky, who worked in the fields of textile, graphics, artist' book, paper art, collage, making objects and writing as well. She started her career as a fashion designer, later experimented with the medium of textile and became an outstanding representative of Hungarian autonomous textile and finally got to painting. She considered her teaching activities carried out parallel with her art work as a work of art in itself. She formed the approach of several generations through her artistic and teaching activities. [1]*

Keywords: *textile, autonomous, genres, contemporary, education*

INTRODUCTION

Margit Szilvitzky is an essential figure in contemporary Hungarian art, therefore it is vital and timely to sum up her career. A book is published of the RESEARCHLAB on the occasion of the exhibition *Margit Szilvitzky: Finding square* presented at acb Attachment between 15 April and 21 May 2021. As a successful fashion designer, Margit Szilvitzky wanted to create something more personal and lasting, therefore she took up stich-work. She made textile collages with yarn, linen-based applications enriched with pearls, and then she enlarged the scales and sewed spatial flags. In the early 60's she starts getting autonomous by decoratively transcribing things and in the 70's she is already researching the basic necessities of space. Through her conscious and consistent research, she got to the geometric and at the same time conceptual artworks. From the second half of the 70's, by the end of the Hungarian spatial textile movement, she painted large, colourful gestures. [2] The present study seeks to explore the complexity of her artistic career, which is difficult to define because of its multiplicity, to show its transforming power on society and approach, as it serves as a useful source for others as well, both in the fields of art and education.

BECOMING AUTONOMOUS

Dresses and creativity

As a young and already successful fashion designer, Szilvitzky has come to the conclusion that clothing design and sewing is not only a livelihood for applied artists but also a program for artists that meets social needs. (Figure 1)

Figure 1: (left) Margit Szilvitzky, 1960's, (right) Fashion drawing, Collection, 1959-1960/tempera, pen, on paper

Clothing has a personal and a societal character at the same time. The conflict between mass production and the expression of personality was already conceivable in the early 20th century. During her early studies of industrial design, she was inspired by the endeavours of the Russian avantgarde of the 1910s and 1920s. The objects designed by e.g. Malevics[2] and Rozanova[3] were characterised by rediscovering tradition, using folk-art motives, simple cuts and decorations. In fashion design Margit Szilvitzky strived to creatively combine series-production and individual needs. [3]

Individuality, participation in the working process/making

As Margit Szilvitzky wanted to make something individual and hand-made, so she went back to old fashioned techniques like embroidery in the course of which she could experience something more personal. She makes more and more textile collage works: threads and pearls on raw canvas to create long lasting and distinctive art. (Figure 2)

Figure 2: Spring, 1967-68, detail

She studied traditional folk costumes to get immersed in the symbolism of folk art. While using different techniques simultaneously, with her assemblages she gets absorbed in the research of the use of material. Her mainly organic wall hangings and textile objects were blown up and became spatial compositions: flags. (Figure 3) In the early '70s her artworks became more settled: simple forms and colours on natural materials. *Flexible Forms*[4]: large size sculptured canvas, represents the three dimensional version of the earlier flat forms. (Figure 4)

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[2] Kazimir Szerenovics Malevics, (1879-1935), Soviet- Russian painter of Polish-Ukrainian descent, a significant representative of abstact art.

[3] Olga Vlagyimirova Rozanova, (1886-1918), Soviet-Russian avantgarde painter, aquarellist, collage artist, book illustrator and poet.

[4] *Flexible Forms* won the first prize in the Textile Biennale of Szombathely in 1974.

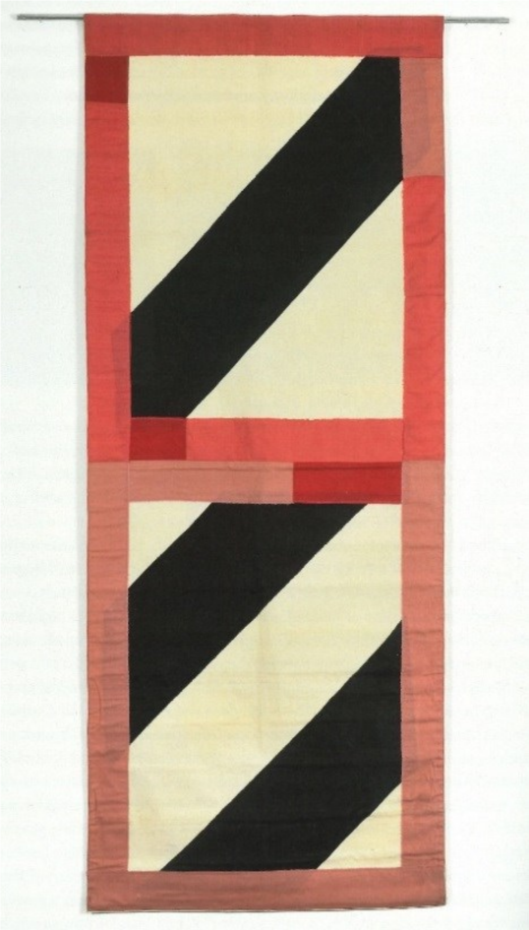


Figure 3: Flag, 1978, applique, sewn, canvas, 236 cm x 100cm

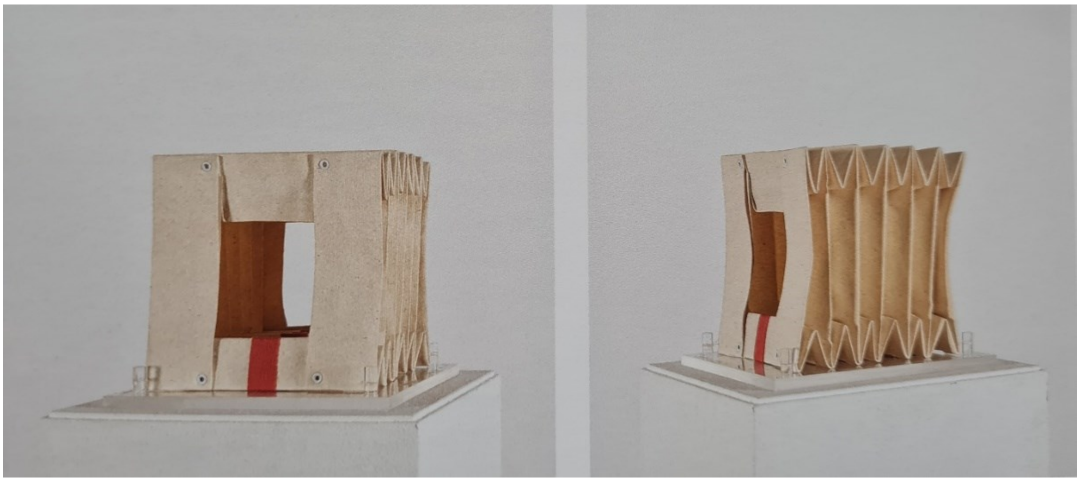
Figure 4: Flexible forms, 1974, wool, sisal, jute, sewing, 2x280x103cm

Research into forms and processes

In the mid-70's Margit Szilvitzky turned to the world of minimal and conceptual art. *"The most exciting part of my carreer was perhaps when I began to work with white canvases. An era of colourfulness came to a close, giving way to a more conscious, analytical period*."- writes Szilvitzky about the shift in her outlook that occurred in the mid-seventies. As an artist of analytical mind, she always followed one chosen objective. [4] Her art series represented already unanimously fine art and can be connected to the art of other Hungarian representatives of fine art[5]. Her textiles shown in exhibition halls had less and less function as useful objects.

Discovering the white square

Margit Szilvitzky's research topics were centred around the clear white canvas, and going out from there she created her geometrically formed series of paintings. An important turning point in her life was when she found the square, the clear form of Malevich. (Figure 5) Later she transformed the consequences of her paper experiments into textile, collages, drawings and space installations. (Figure 6)



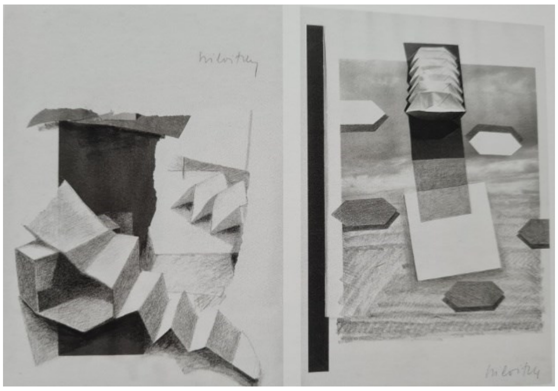


Figure 5: Interior, 1977, constructed, folded linen, ribbon, 20x20x20cm

Figure 6: Drawing Montage (Hexagon), 2004, photo, print, pencil on paper, 29x20cm

[5] The serial works of Péter Türk, the foldings of András Mengyán, pliage-technique of Simon Hantai, pleated textile-reliefs of Aranka Hübner, mathematically systemised foldings of Tibor Gáyor, square-cube based pseudo of Gyula Pauer.

Painting and Grand Art

In the late 70's Margit Szilvitzky sewed colour collages from different materials. By the mid 80's she finished the painted applied variations of her series of *'Ribbon stories'*. Parallel with the wave of new painting her works return to the two-dimensional mode, she paints sensible and expressive free canvases on laufers. [6] (Figure 7)

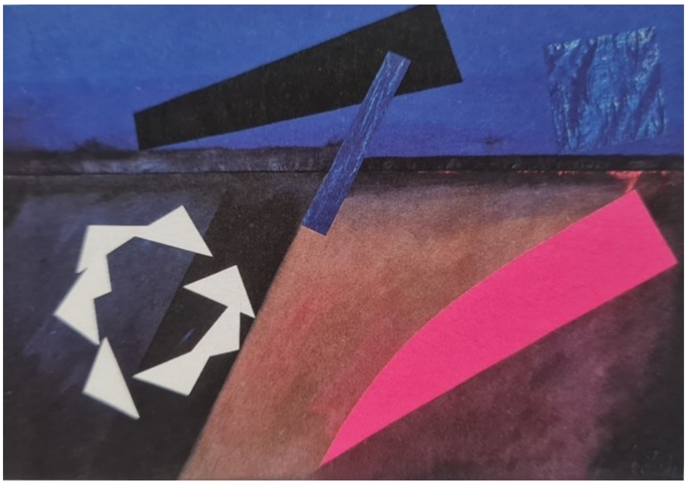


Figure 7: Ominous Hour, 1987, fabric, canvas, silk, linen, 220x310cm

EDUCATION

During a two-year course named "Art studies", Margit Szilvitzky strived to form the attitude of the students according to the approach of that age, providing them with the latest news and information, and assigning them art process tasks. In the framework personal correction, she gave the students every week new tasks tailored to the person, according to the theme of research chosen by the student. By the end of these series of tasks the students had acquired a contemporary vision of art and with a sound professional basis they could continue they art studies. At the same time, they built up their own visual vocabulary. (Figure 8)

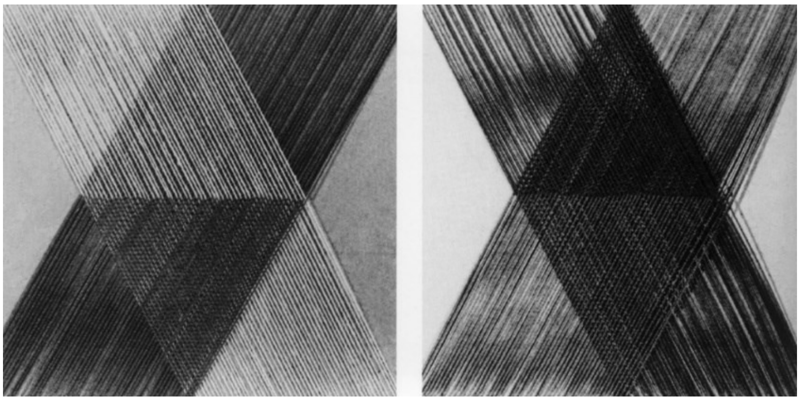


Figure 8: Mariann Bánffy, constructions with thread in flat and space (student's work).1981.

[6] Laufer is a back cloth of handmade printing

SUMMARY

The review of the oeuvre of Margit Szilvitzky can be an example for the artist of the contemporary generation and for their teachers of art as well. She transferred and utilised the results of her research in the field of education. With an ongoing research of the tendencies in art of her age, with her experience gained throughout her individually and consequently built up thinking based on processes led her to more and more clear visual solutions. (Figure 10)

Her methods and strategy consciously elaborated in the field of education gave guidance for whole generations of artists in the long run. The years gone by since her creative artistic work and educational activities have proven this change in the attitude to art. Margit Szilvitzky was an outstanding personality and creator of her age. I am proud and grateful that I could be her student, and later, after the late 70's her colleague. With an excellent artistic foundation and creativity she launched me on my artistic career, therefore I am entitled to call her my master.

Figure 10: Quotes, 1969, 1972-1986., Reconstruction with original materials and fragments, Margit Szilvitzky's exhibition, Kunsthalle, Budapest, 1988.

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ADVANCED TECHNOLOGIES AND FEATURES OF THE BUDAPEST METRO LINE 4

Lisa WAWCZAK, Edit CSANÁK

Abstract: *This article presents the results achieved within the course 'Project Work' and carried out on observatory analysis and research on the technical features and advanced technology used on the Budapest metro line 4. Since a pretty small number of writings are available in English about the metro lines of Budapest, the research has been carried out based on individual observation and technical interpretation of what was seen. The attention in this research was on the understanding of what is seen. The focus was on five M4 stations, particularly their innovative technological solutions. To carry out this project, we visited each station of the M4. Because of their particularities, we decided to focus on five of them: Kálvin Tér, Rákóczi Tér, Szent Gellért, Újbuda-központ, and Bikás Park stations. Because the stations on Budapest's metro line 4 are particularly distinctive in design, this project investigated their technological aspects. After introducing the line and five of its stations, the documentary and technological elements were highlighted by comparing them to the line 1 stations. Finally, the Szent Gellért and Fővám Tér stations' technical features were reviewed.*

Keywords: *engineering, technical sciences, architecture, metro construction, design functions*

THE INSTRUCTORS' FOREWORD

Project Work provides an excellent way for personal development on many levels. It stimulates problem solving, self-esteem, and confidence of the student. Analysis of the local culture plays a vital role in the methodology of the course. Learning about the historical values of local architecture and researching the importance of the built environment can be one of the topics offered to an international student, for example. According to the general education goal, the project must enable the student independently to carry out project work comprehending experimental and empirical, or theoretical investigation of one or more ways of presenting problems within central subjects of the student education.

Projects can be set up in different fields: Textile-, Garments, Paper-, Printing design and technology, Marketing, Quality and Environmental Management, Environmental engineering. Project works can be various:

- Making leaflets, posters, booklets, or websites with information on different topics;
- Designing fabrics-, garment-, leather goods- collections, and fashion designing;
- Creating blueprints;
- Methods, analyses, technology research in diverse fields of technical sciences, the area of art, and design.

According to the general education goal, the *project must enable the student independently to carry out project work comprehending experimental, empirical, and/or theoretical investigation of one or more ways of presenting problems within central subjects of the student* *education.* [1] Topics of the practice work with terms and descriptions of the tasks are usually detailed in the form of a '*4 point schedule'* – in line with the general product design and product development methodology. [1] (Table 1)

Table 1: General topics of the practice work with terms and description

Week	Topics with a brief description:
1-3	Confirming of the thematic for project work and scheduling with the tutor
4-7	Background research
8-12	Problem-solving (collecting ideas and creating something)
13-14	Make a presentation about the project work before the group introduces the readymade product (if available).

The eight-credit course' Project Work' has been chosen by an incoming student from a Technical Faculty from France. The assignment addressed to the student was in the analysis of forward-looking technologies on the Budapest metro line 4, with analysis of 5 stations chosen, and introduction of advanced technologies of one of the stations, and the technical and documentary product functions of the technology solutions [2].

INTRODUCTION

Moving people through transportation networks efficiently and effectively is a complex undertaking. Metro stations are complicated infrastructures that link numerous train lines overlapping small spaces. With population development and urbanization bringing more people into cities than ever before, metro stations, the beating heart of city life, transporting people from home to work and other everyday destinations are confronting unprecedented mobility and efficiency challenges.

Cities construct these locations to be more like living spaces to improve everyday travellers' experience. An attempt is being made on the station's design to integrate it into the cities and is already made for the constructions. This is also the case for the Budapest metro line 4, which is unique in that it was designed to be both functional and aesthetically pleasing. Indeed, design teams worked on the station's construction project to make this place, usually dark, cold, and soulless, lighter and airier.

This work aims to present our research on the technical feature of metro line 4 by introducing the metro line and five of its stations, describing their features, and discussing the technical aspects of one of them.

THE BUDAPEST'S METRO SYSTEM

The metro in Budapest

The metro is one of the essential transports in Budapest. There are two types; the first is the Millennium Metro, the first line, which opened for the millennium. After the London Underground, it is Europe's second-oldest underground electric train line. This historic architecture is still present today. The two pictures hereafter show this train at its origin and nowadays.

Figure 1: Comparison of the Metro Line 1 at its beginning and today

The others are the metro lines created under the communist system in the '70s, the second and the third lines. There were extended with a fourth line, open in 2014. With one hundred metro transits in operation every day, not less than 80 thousand boarding pa ssengers every workday use metro line 1, 350 thousand for line 2, 500 thousand for line 3, and 185-195 thousand for line 4. (Fig. 1)

Metro line 4

The fourth line of the Budapest Metro is officially named South Buda- Rákospalota line or Metro 4 (M4) and unofficially the Green Line. It connects the Buda and Pest sides of the city and deserves ten metro stations. (Fig 2)

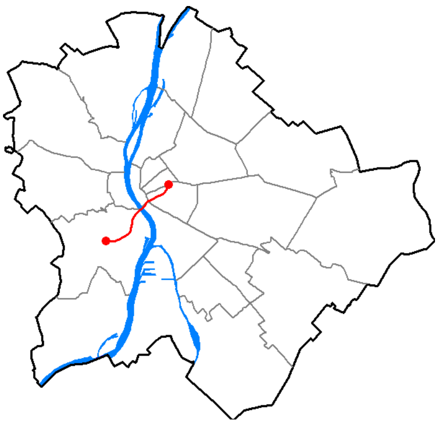

Figure 2: Map of the Budapest metro line 4 and Stations served by the line

In May 1991, the decision was made to begin the project. Due to difficulties obtaining the necessary funds, permits, and agreements, the project's construction did not start until March 2006. However, other challenges such as collapses and ownership issues were encountered, and the construction was completed in 2014.

For decades, the M4 project has been the city's largest infrastructure project. The line can be viewed as a building with ten wings, each with its atmosphere. Through the new aesthetics and high architectural quality of a series of new public spaces in Budapest, designers' goal was to provide attractiveness to a place that was often only designed to be functional. Five architectural firms collaborated on the unique design of the individual stations.

The focus was on five M4 stations. To carry out this project, we visited each station of the M4. Because of their particularities, we decided to focus on five of them: Kálvin Tér, Rákóczi Tér, Szent Gellért, Újbuda-központ, and Bikás Park stations. The description of each of these stations is given in this section.

Kálvin Tér Station

Kalvin Tér station is the largest station built beneath a busy inner-city square as an interchange station between the M4 and M3. The complex functional requirement necessitates the development of complex spatial arrangements with large open spaces over platforms facilitated by cut-and-cover construction technology. This is the oldest tunnelling method: it entails digging a trench, building a tunnel, and returning the surface to its original state. (Fig 3)

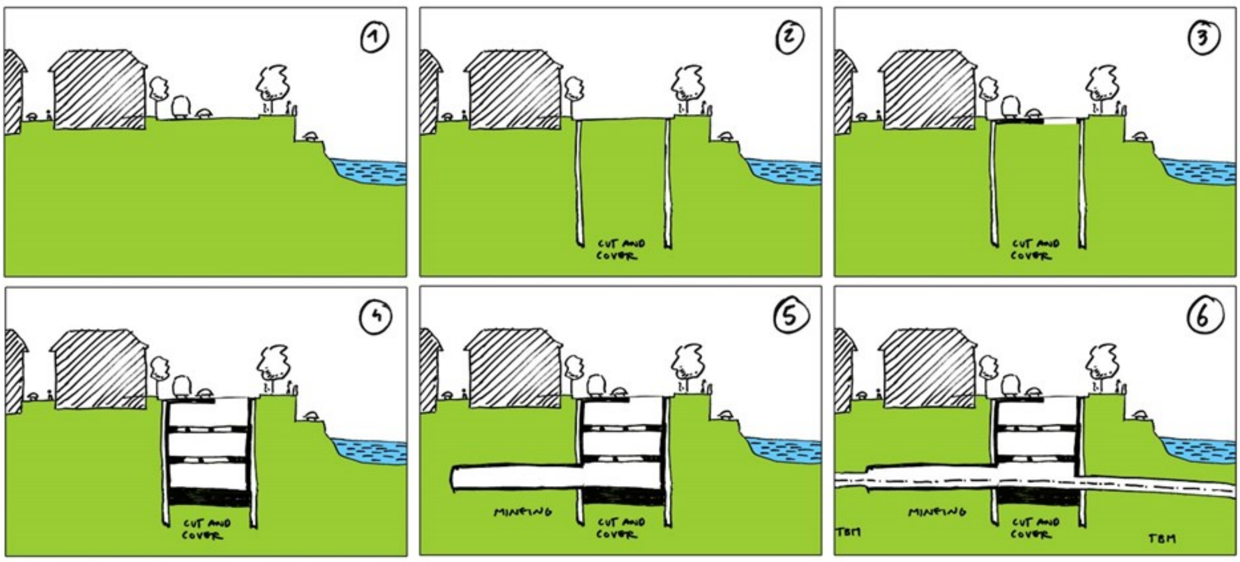

Figure 3: Steps for the metro's construction

Large open spaces are made possible by more extensive and smaller openings for natural light from the surface, providing the station with an atmosphere of free and airy spaces. Concrete is widely used as a primary structure, while those elements, closer to the traveller, are on a finer human scale.

Figure 4: Picture of Kalvin station

Bikás Park Station

This station is notable for its glazed dome, which provides natural light to the platform's main entrance. During the day, there are shades and light in the station's depths. The station's graphic design echoes the park's impressions with flowers on fiber-concrete cladding and flying seeds on glazed smoke shields. The dome is a slim, lightweight structure that sits over the elliptical opening in the platform ceiling and is made up of a grid of triangles, some of which are glazed and some of which are solid for shading. On hot sunny days, the openings in the backbone provide ventilation for the dome, adding some irregularity to the pure geometrical form.

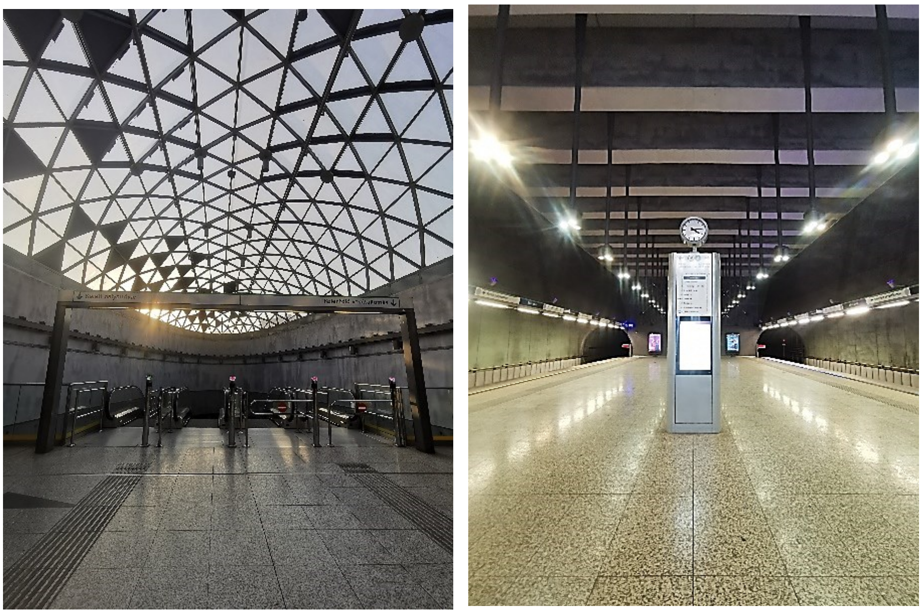

Figure 5: Pictures of Bikás Park station

The tween stations Szent Gellért and Fővám tér are the deepest on the line, located on opposing banks of the Danube. These stations are distinguished by crisscrossing reinforced concrete beams at various levels, which are inspired by the structure of bone tissue. This architectural choice eliminates the need for columns, allowing the platform areas to become open and continuous spaces. Ground-level crystal-shaped skylights supplement the artificial lighting, creating a play of light and shadow within the hollow interior as light is projected onto the overhead beams. Both stations' entrance and circulation areas have weathered steel panels applied to the walls to provide a warm contrast to the concrete surfaces.

Tunnels within the Szent Gellért tér station have been decorated with a swirling mosaic by artist *Tamás Komoróczky*, which references the tiles used inside the nearby Gellért Hotel.

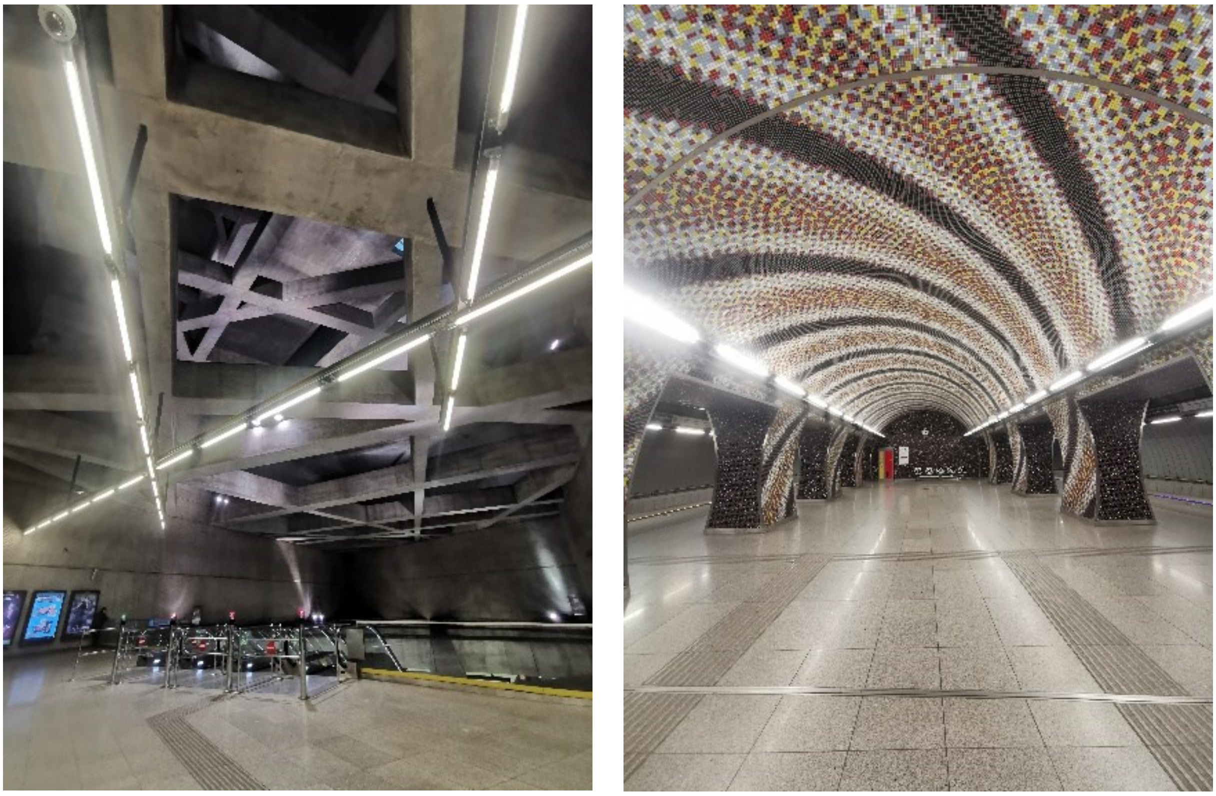

Figure 6: Pictures of Szent Gellért and Fővám Tér stations

Rákóczi Tér station

The Ráckóczi Tér station is noticeable by its contrast between dark and light. The large internal space is exacerbated by two columns made with glass and unique mirrors, which provide natural light to the station. Particular mirrors have also been affixed between the concrete discs of the station's ceiling, which will scatter light into the station from spotlights directed at them.

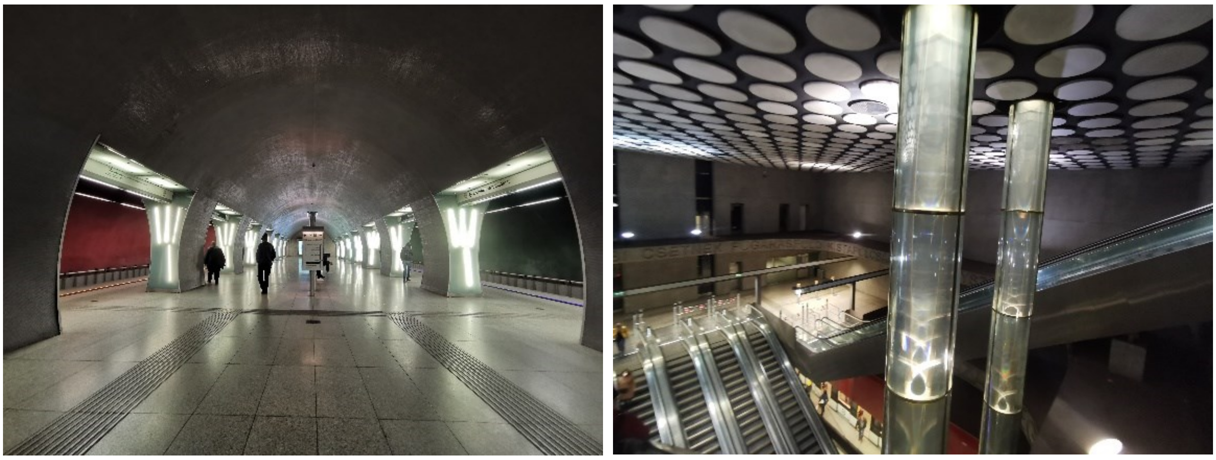

Figure 7: Pictures of Ráckóczi Tér station

Újbuda-Központ station

The usage of glass as a material distinguishes this station. It is seen at the station's entrance. This colored material, which is noted for being fragile, delicate, and light, contrasts with concrete, which is hefty, cold, and dense. The glass may also be found at the station's bottom, where bubble glass panels cover the whole wall, giving the effect of a waterfall. The ceiling is covered by a textured material similar to a crumpled aluminum sheet.

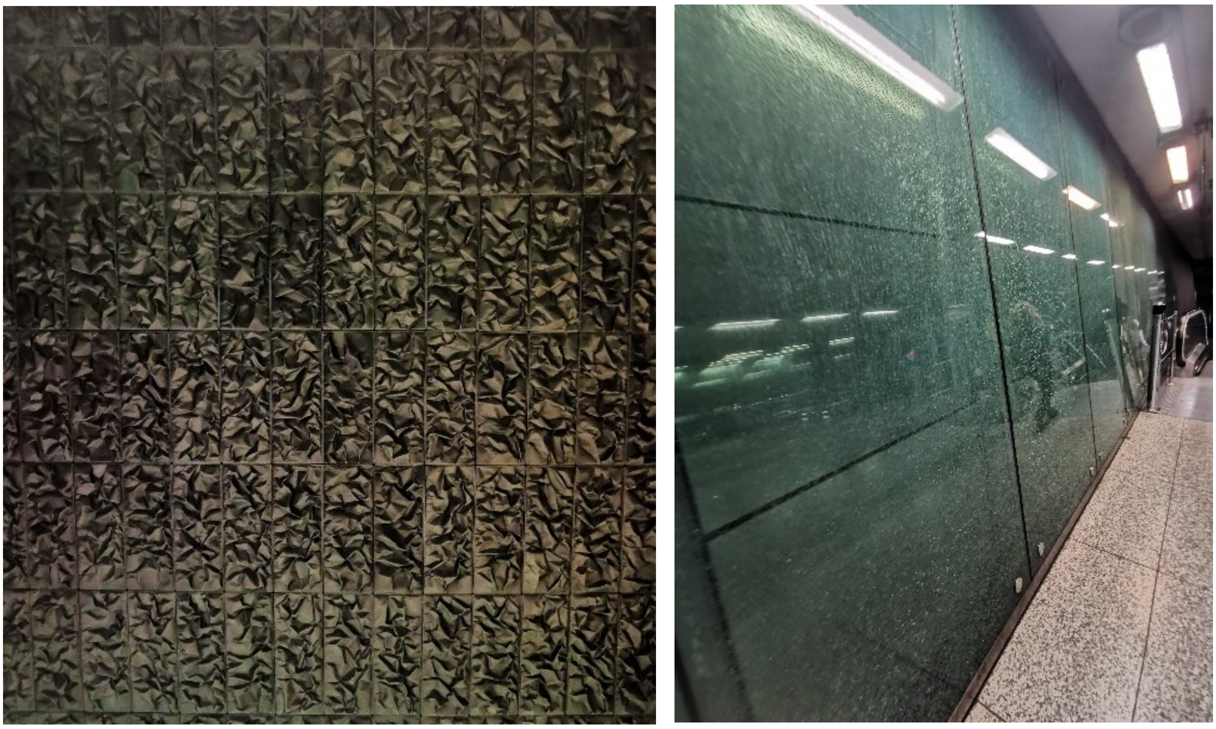

Figure 8: Pictures of Újbuda-Központ station

The analyzed features give us information about when the contractions were made and their technology. In the following chapter, we will discuss these features of the construction.

THE DOCUMENTARY AND TECHNICAL FEATURES OF THE STATIONS

To describe the documentary and technical features of the M4 stations, we will draw a comparison between them and the M1 stations, which were built decades earlier. These two lines can be distinguished by some aspects, which will be discussed in this section.

The station shape

When entering the new stations, the first noticeable feature is their shape. Their deep position allowed the creation of a void under the ceiling to provide a feeling of space. Designers are now considering void as a new raw material for architects. They highlight it with the play of light and vertical elements that direct the look of passengers upward. The M1's stations have low ceilings; only the opposition created the necessary place.

Figure 9: Pictures showing the shapes of the stations

The materials

The second features that characterize the new stations are the materials used for their construction. While older stations were made with materials that have been used for centuries, such as wood for doors and desk elements, iron metal for windows and columns, and ceramics for wall coating, newer stations use more recent and innovative material. Concrete is used mainly for the main structure due to its fire resiliency, load resistivity, and durability. Glass elements bring natural light into the station and metal such as aluminum and iron to structure the space. (Fig. 10, next page)

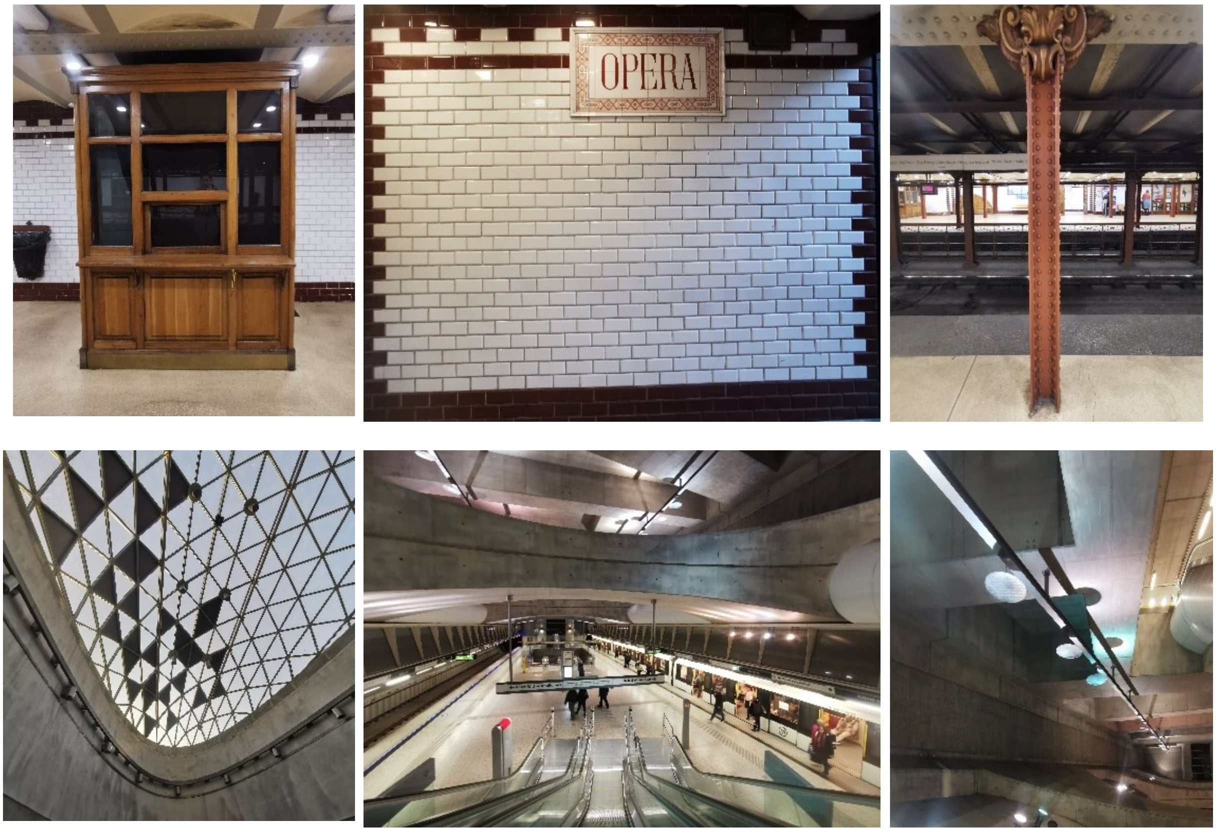

Figure 10: Pictures of the materials used for the construction in Budapest's metro stations

The design

The design of the new stations is very contemporary. First, the colors are used to contribute to the atmosphere of the place. While the colors used in the M1 station are warm due to the use of wood, red, and white that brings light, the colors used in the M4 station are colder. The structure elements are frequently crude, giving way to the grey of the concrete. Bright colors are used to contrast with a mosaic drawing in the Fővám Tér station and colored lights in the Keleti Pályaudvar station. Attempts were also made to make the structure of the stations more complex and thus designed. Consider the Szent Gellért station and its impressive concrete structure.

Figure 11: Picture of the celling's texture of Újbuda-Központ station (left), and color contrast of Fővám Tér station (right)

The stations are functional, but they are also meant to be admired. The element used to direct the passenger's gaze upward reveals the artistic textured ceiling like the white circles of the Ráckóczi Tér station or the textured top of Újbuda-Központ station. The designer did not overlook the furnishings designed to complement the stations.

Figure 12: Picture of the furniture in the M4 and the M1 stations

The technology

The M4 stations use modern technology to facilitate the experience of travelers. Indeed, the stations, which are located deep underground, are equipped with automatic stairways and elevators. Besides making passenger travel more accessible, automatic stairways make the passenger flow more fluent, especially at peak time, and also more accessible. A blue indicator on the station floor also indicates the arrival of the metro in the station. The warning is intended to warn heated passengers of the danger presented by this arrival.

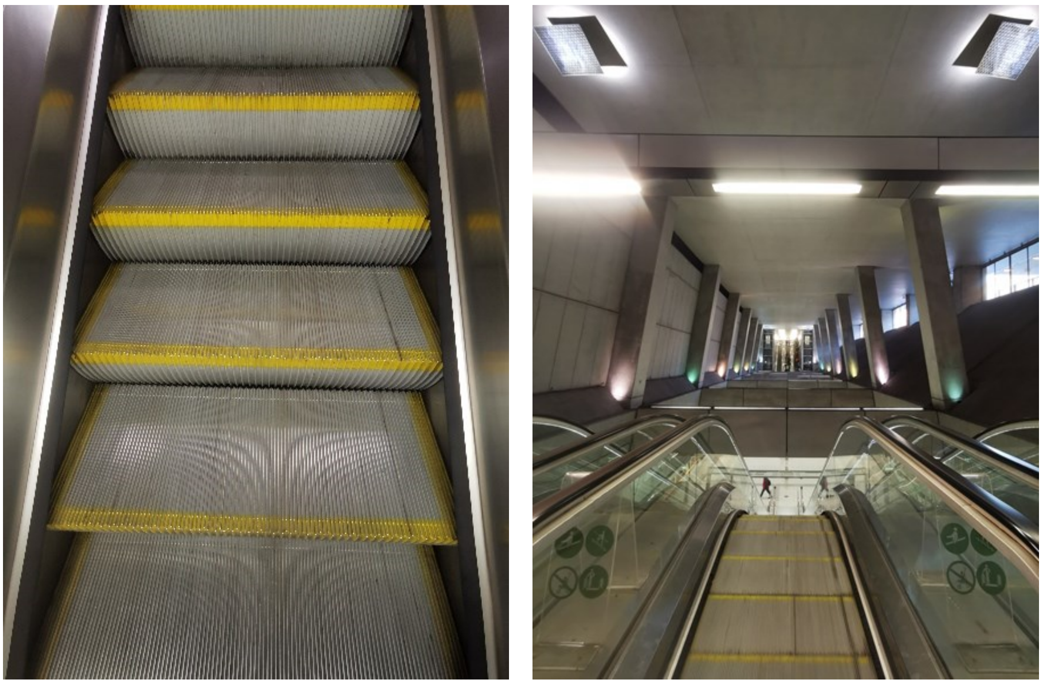

Figure 13: Pictures of the new and old automatic stairway constructions

DISCUSSION ON THE SZENT GELLÉRT AND FŐVAM TÉR STATIONS' TECHNICAL ASPECT

Description of the structure

Because both stops are near the Danube, the station's structure must absorb the massive forces involved. The choice was made to realize crisscrossing reinforced concrete beams. In addition to being aesthetically pleasing, this structure provides a solution to the existing constraints.

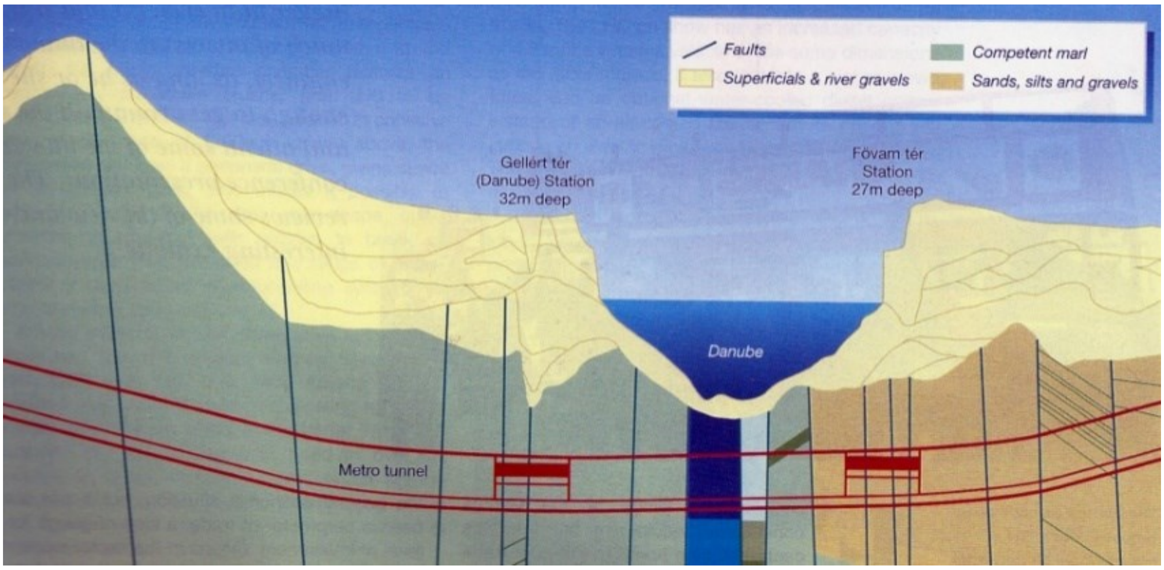

Figure 14: Image of the position of the two stations in relation to the Danube

Choice of the structure

The bone structure inspired designers. There are some similarities between the two. Bones are designed to withstand daily mechanical challenges, resulting in various loading modalities with varying magnitudes, directions, rates, and frequencies.

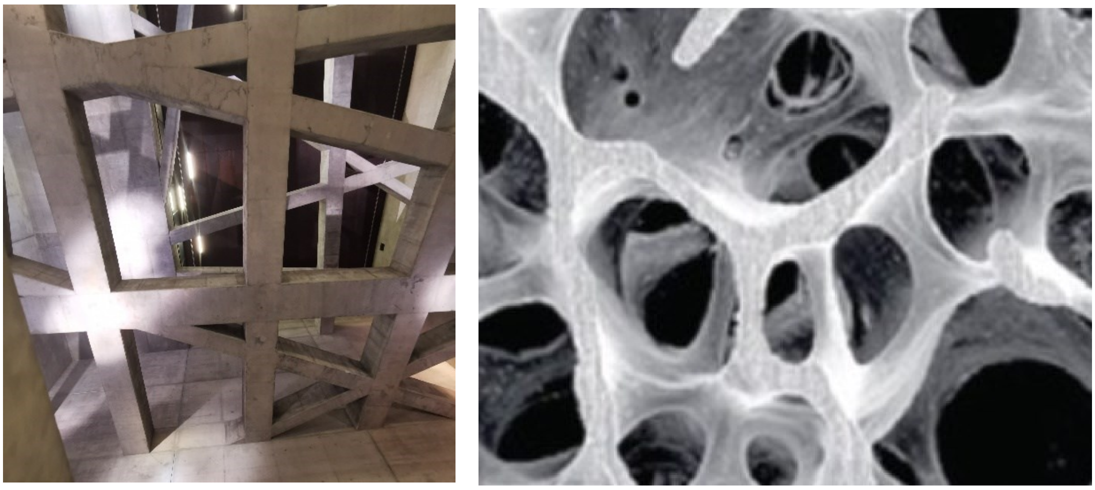

Figure 15: Picture of the concrete structure (left) and image of the bone structure (right)

The porous structure enables the load distribution in the whole system and provides elasticity to the whole. A concentrated force would breach it. The graph below depicts the relationship between the constraint and the deformation. Each material has its unique reaction. The material can revert to its original structure when subjected to a constraint under the yield force. However, if this point is exceeded, the structure loses its elasticity, becomes more fragile, and may collapse.

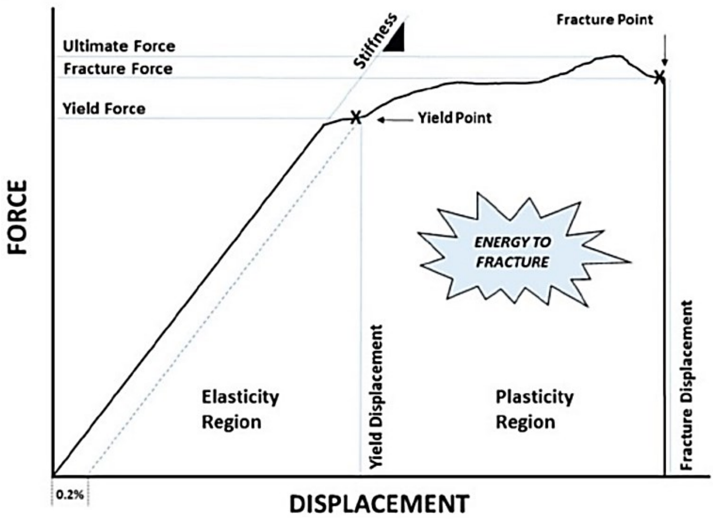

Figure 16: Graph depicting the relationship between constraint and displacement

Choice of the material

Reinforced concrete was used to build this structure. It consists of concrete in which steel is embedded so that the two materials act together in resisting forces. Concrete is often preferred as a building material over other options since it is cost-effective for the construction industry. Concrete has a far higher compression strength than any other material, yet it has a tensile merger strength. The reinforcing steel (rods, bars, or mesh) absorbs tensile, shear, and sometimes compressive stresses. In reinforced concrete, the tensile strength of steel and the compressive strength of concrete work together to allow the member to sustain these stresses over considerable spans.

There are numerous concrete reinforcing solutions available. Even though some steel qualities are compatible with concrete, steel was chosen above other materials. Steel and concrete have comparable thermal coefficients. It also does not require any extra tie-up during concrete installation because it will not float over the concrete. Its ease of manufacture, recyclable nature, and superior bendability on-site without adverse effects on the section make it a preferred material above others.

Figure 17: Picture of reinforced concrete

SUMMARY

We learned more about a particular aspect of Budapest's life through this work, focusing on aspects we would never see otherwise and visiting locations we would never travel through otherwise. It was also an opportunity to recognize the particular relationship between design and engineering in this architectural project.

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EMBERI ERŐFORRÁSOK MINISZTÉRIUMA

Nemzeti Tehetség Program

ISSN 2786-3638