

VISUAL PERCEPTION EVALUATION OF CORTEN STEEL: ŞİMAL SHOPPING MALL

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Abstract

Corten steel, or the corrosion of steel, is a result of exposure to the atmosphere. Corten steel is a recyclable, energy efficient, durable, and aesthetic material in terms of sustainability. This study aims to challenge the negative perceptions of Corten steel in society, stemming from its color and texture characteristics; and emphasize its importance in terms of sustainability and to prevent the prejudice of society. The purpose of the study is to determine the perceptions and satisfaction levels of Şimal AVM users towards Corten steel used as façade material. It is expected that the work will have an awareness-raising effect on the Corten steel material, which can create a perception of “deterioration” and “rusty”. The sample of the study consists of 221 users who have experienced Şimal AVM at least once. Additionally, a meeting was held with the architects of the building on the subject. As a result, Corten steel has a negative perception among users, primarily comprising negative (rusty, dirty, unhealthy etc) perceptions in physical, environmental, and emotional terms. However, after the study, it was determined that there were users whose perspective on the material changed.

Keywords: Architecture; Corten steel; Façade design; Sustainability; Visual perception.

1. INTRODUCTION

Sustainability has become an even more important issue with increasing consumption. The use of recycled products is preferred in the field of architecture, both economically and environmentally. In addition to structurally recycled spaces, the use of sustainable materials directly in the construction and design process of the building is a desired and expected practice in this century, where natural resources are rapidly depleted. Corten steel is a sustainable material used in the field of architecture, as well as being preferred in many areas.

Corten steel belongs to a family of steel alloys devel-

oped by a steel company to eliminate the need for paint and achieve a long-lasting rusty appearance. Designed in 1933 by the company for use in railway wagons carrying heavy loads, such as coal, metal ore, minerals, and grain, and is a mechanically improved steel [1]. Corten steel is known as a low-carbon (0.05% to 0.3%) steel. Steels resistant to atmospheric corrosion, including Corten steel and structural carbon steels, are steels that are actually strengthened against corrosion by adding 2% or less of common alloying elements such as copper, phosphorus, chromium, nickel and silicon [2].

Steel materials that are resistant to atmospheric corrosion, such as Corten steel, can have different

The Process For Producing Corten Steel

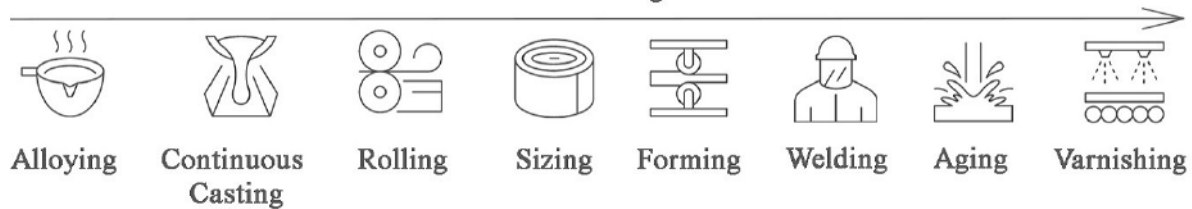


Figure 1.
The process for producing Corten steel [Created by authors]



Figure 2.
Transforming the Hokkaido Centennial Memorial Tower over the years [8]

physical and mechanical properties thanks to the alloying elements in certain proportions that are added to them while they are still in liquid form. After the alloying process, the production phase is summarized as follows (Fig. 1). The stages include continuous casting, rolling, sizing, shaping and welding. The subsequent aging process is applied to accelerate the formation of the protective layer on the material. This application involves dipping the material into a H_2SO_4 (sulfuric acid) solution. After the steel material has dried, the surface is fixed with polyurethane varnish, which prevents surface wear. They can be produced up to 20 cm thick [3].

Corten steel is widely used globally in construction, particularly for bridges and towers, due to its exceptional corrosion resistance and high strength. Understanding the corrosion mechanisms and the role of corrosion inhibitors, particularly at the initial stage, is crucial. However, most recent research on corrosion and inhibition focuses on electrochemical experiments with in-situ examination of treated steel surfaces [4]. Corten steel has better corrosion resistance and high mechanical properties, so it is widely

used in regions where there is water [5]. The color-changing surface and chemical properties of Corten steel are also one of the reasons why it is preferred. This feature is used especially in sculpture arts [6]. The reason for the color change is that it forms a corrosion-resistant oxide patina over time in outdoor conditions, and this situation continues [7]. Fig. 2 shows the color change of the Corten steel material used on the façade of the Hokkaido Centennial Memorial Tower over a 41-year period.

Corten steel is recyclable, suitable for reuse, durable, energy efficient, and flexible in terms of environmental sustainability. It is a healthy and aesthetic material that can be applied quickly and easily. Compared to ordinary carbon steel, the construction time is shorter and the life cycle cost is lower. Corten steel is long-lasting and provides protection against natural disasters. It can renew itself and requires less maintenance. In addition, it does not require any painting or coating material [9]. Müller et al. (2019) determined in their experimental study that the steel group, including Corten steel, emitted less than metals such as copper and zinc. With the sample projects they



Figure 3. Closing the gap in the eastern rooms of Kyrenia Castle with Corten and new access to the Eastern fighting gallery and Venetian filling [16]



Figure 4. Raif Dinçdök Cultural Center, Özyeğin University Faculty of Architecture and Design Building, Piri Reis University and Tekfur Palace Museum [created by authors with photos from [17]]

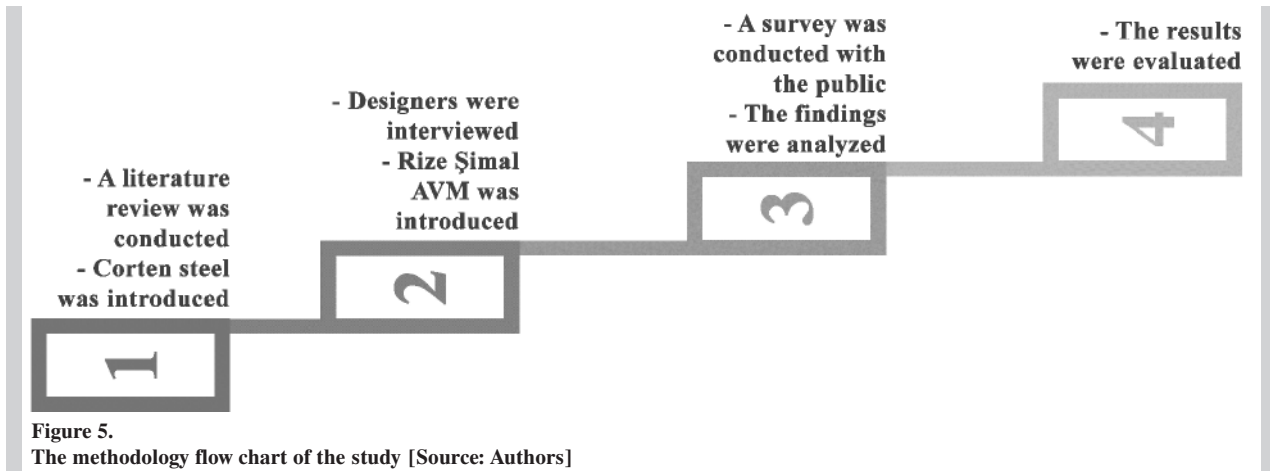
examined, Kim and Kwon [10] emphasized that pollution was minimized by using thermoplastic paint and Corten steel sheet, which they described as environmentally friendly materials, and economic profit was achieved as a result of strengthening the existing situation with these materials instead of reconstruction. Thus, it was concluded that both economic, social, and environmental sustainability were achieved.

It is generally preferred in the construction industry, especially bridges, buildings and telecommunication towers [11, 12]. Marchwiński [13] emphasizes that Corten steel is a material identified with the industrial world. Corten creates a strong design when used appropriately. It also plays both an aesthetic and metaphorical role. The use of Corten steel in architectural expression dates back to the 1960s. One of the pioneers of this practice is the famous American-Finnish architect Eero Saarinen [14]. Widely used as an interior finishing material, the Corten plate plays a special role in developing the symbolic code of architecture [15]. In addition, the material is used in vertical form to prevent rusty residue from causing stains. Valetta and Camiz [16] emphasized that the Corten steel used to fill the gap on the façade of The

Castle of Kyrenia, located in a historical environment, without damaging the originality and architecture of the material, increased the accessibility and historical spatiality of the monument (Fig. 3).

It is seen that Corten steel, a material more commonly used in the field of architecture abroad, has also been preferred in Turkey for facade design, especially in recent years. Sample projects where Corten steel material is used include the Raif Dinçdök Cultural Center, Özyeğin University Faculty of Architecture and Design Building, Piri Reis University, Tekfur Palace Museum, and Rize Şimal Shopping Mall [17] (Fig. 4).

In addition to the fact that Corten steel is a particularly durable and long-lasting material, studies in the literature generally examine its technical properties. On mechanical behavior and corrosion resistance [4, 12, 18–22], on durability [23, 24]. Although studies on its use in construction and production [1, 25] and on air pollution and sustainability [26–28] are common, in the field of architecture, Corten steel is generally used in restoration works and architectural coatings or It appears in urban coverings and modern and contemporary works of art [11, 29–31].



Corten, a material notable for sustainability, is new to the field of architecture. Kunawong [32] stated that the appearance of Corten steel, which he stated was produced with aging steel technology, resembles the appearance of natural rust and creates a paradigm shift in rust perception in designs. In this regard, the question arises of how people perceive a material with a rusty or deteriorated appearance. In this regard, research was conducted on the users of Rize Şimal Shopping Mall, which is covered with Corten steel.

2. METHODOLOGY

The aim of the study is to determine how Corten steel creates a perception in users when used as a facade material. Within the scope of the study, it is aimed to raise awareness and answer questions for Corten steel material that may create a perception of “deterioration” and “rusty”. To achieve this goal, the study focused on Şimal Shopping Mall in the Rize province of Turkey, where Corten steel is chosen as the exterior cladding material. Deterioration or corrosion of steel occurs as a result of exposure to the atmosphere. This is an electrochemical event that refers to a reaction that occurs under humid conditions and in air [2]. These reasons were effective in the selection of Şimal Shopping Centre in Rize. Rize city is located in the east of the Black Sea Region. The settlements in Rize, which has a very mountainous and rugged topography, were established on the plains and valley slopes formed by the alluvium carried by the rivers on the coastline. The abundant rainfall in all seasons of the province with temperate climate characteristics is the most important factor in the development of lush forests and large green areas [33, 34].

To gauge user perceptions within the study's scope, a voluntary questionnaire was administered using Google Forms. The survey sought the opinions of individuals who had experienced the shopping center, covering their demographic characteristics, views on the project's design, and assessments of the color and texture of the material. Additionally, participants were provided with brief information about Corten steel, and their opinions on the material, as well as any changes in perception, were recorded.

Furthermore, interviews were conducted with the designers of the shopping center, involving prepared questions. Architects were queried about the reasons behind selecting Corten steel, the relationship between the material's qualities and this decision, and the societal significance of the material's attributes. The method flow chart of the study is presented in Fig. 5.

2.1. Study Case: Rize Şimal Shopping Centre

The Şimal Shopping Mall project, which was designed with the aim of building closed streets and outdoor activities where people can shop in the city of Rize in the Eastern Black Sea Region, started in 2014 and was opened in 2023. The project area is 30.250 m² and the construction area is 118.000 m² with a total of six floors including ground floor, three normal floors and two basement floors. Rize, a growing and developing city, needs an attraction point and landmark buildings that will create identity and attraction to the city. Especially in the region where black tea is at the forefront as a source of economic income, the idea of making a design inspired by the tea flower has been the main goal of architectural designers [35]. Corten steel material was preferred as the exterior cladding of the building, which has an



Figure 6.
Rize Şimal shopping mall exterior [Source: Authors]



interesting facade design in its region. The holes of the perforated cladding also reveal a picture of nature when viewed on a large scale (Fig. 6).

The design team stated that the main factor in choosing Corten steel material was aesthetic concerns. Although Corten steel is an expensive material, it was chosen because it was wanted to be one of the symbolic structures in Rize. In addition, the fact that the material does not require maintenance and is a living (continuous) material has influenced its selection. For this reason, the minimal pollution impact on the surroundings was deemed acceptable. The material's usage in England, which has a similar climate, influenced its selection. The material was delivered to the construction site sized according to the unit dimensions and directly assembled.

3. RESULTS

In this section of the study, the demographic characteristics of the individuals participating in the survey and their answers to the survey questions are included. More than half of the individuals participating in the survey (62%) were women and 38% were men. Considering the age range of the individuals participating in the survey, it was seen that the 18-25 age group participated the most (35.3%). This age group is followed by the 26-35 age group with a rate of 33%, the 36-45 age group with a rate of 22.2%, and the 46-55 age group with a rate of 6.3%. The lowest participation among age groups was 56 years and over, with a rate of 3.2%. More than half of the individuals participating in the survey (57%) have undergraduate degrees, 34.8% have graduate degrees, 6.8% have associate degrees and 1.4% have high school degrees (Table 1).

The participants were asked about their level of satisfaction with the building design, facade design, mate-

rial, colour, and texture of Şimal Shopping Mall. The participants responded to the question of whether they were satisfied with the building design of Şimal Shopping Mall, with the highest rate being 36.6%. In addition, 23.9% of the participants stated that they were not satisfied at all. In response to the question about the level of satisfaction with the facade design

Table 1.
Demographic characteristics of participants [Source: Authors]

Gender	Number of people (N)	Percentage (%)
Female	137	62
Male	84	38
Age	Number of people (N)	Percentage (%)
Between 18-25	78	35.3
Between 26-35	73	33
Between 36-45	49	22,2
Between 46-55	14	6,3
56 and above	7	3.2
Education	Number of people (N)	Percentage (%)
High school	3	1.4
Associate degree	15	6,8
Graduate	126	57
Postgraduate	77	37.8

of Şimal Shopping Mall, almost half of the participants (43.4%) were not satisfied at all, and 26.6% of the participants were not satisfied. The majority of the participants (47.5%) stated that they were not satisfied at all with the facade material of Şimal Shopping Mall. More than half of the participants (53.3%) expressed dissatisfaction with the colour of the facade material of Şimal Shopping Mall, and 25.35% of the participants stated that they were not satisfied.

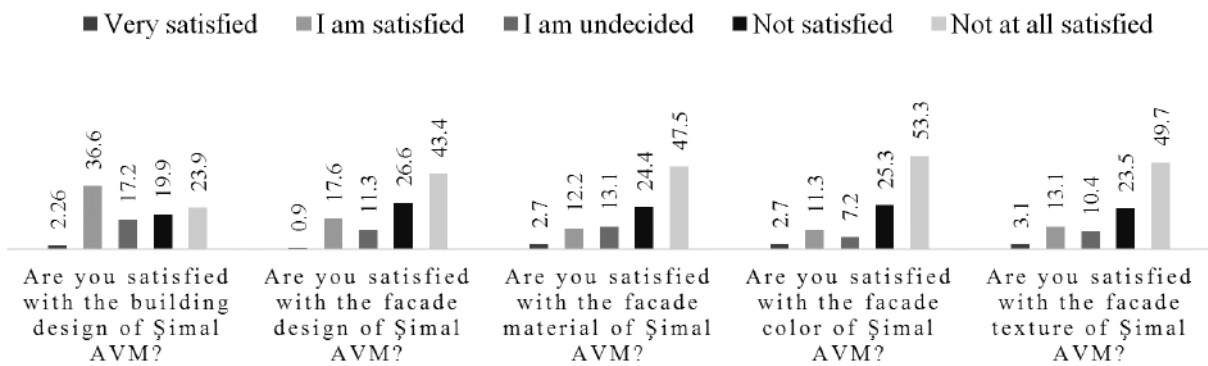


Figure 7. Participants' satisfaction levels with the building design, facade design, material, color and texture of Şimal AVM [Source: Authors]

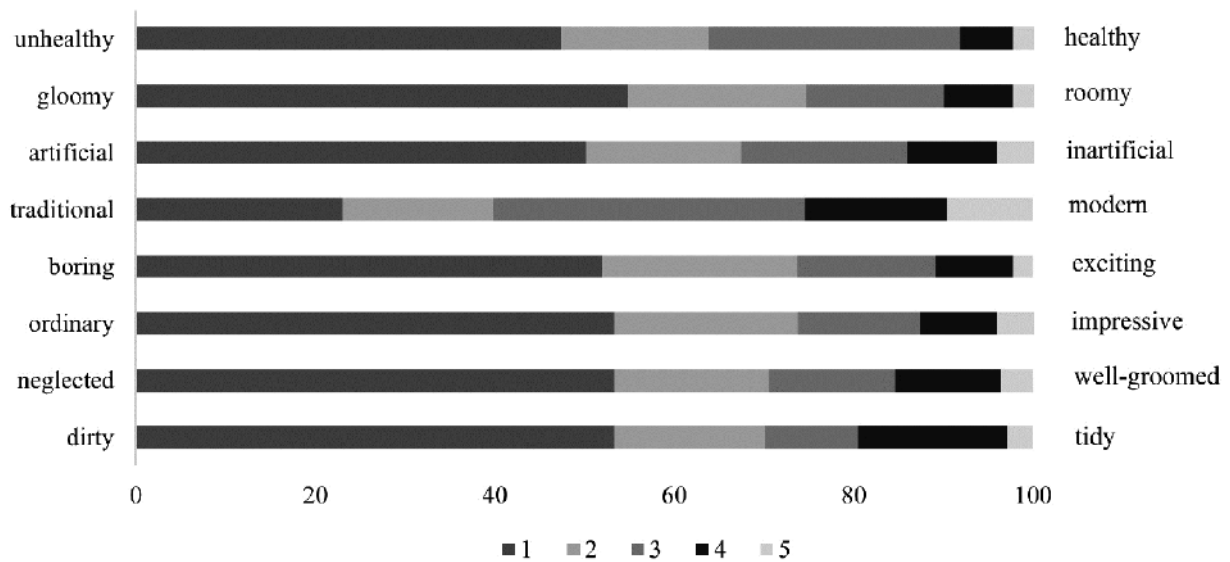


Figure 8. Participants' opinions about the facade of Şimal AVM through adjective pairs [Source: Authors]

Almost half of the participants (49.7%) indicated dissatisfaction with the facade texture of Şimal Shopping Mall, while 23.5% of the participants stated that they were not satisfied at all (Fig. 7).

Participants were asked to express their opinions on the facade of Şimal Shopping Centre using adjective pairs. The results indicate that 47.5% of the participants find the facade to look unhealthy, while more than half (54.8%) find it gloomy. Additionally, half of the participants (50.2%) perceive the facade as artificial, 34.8% consider it both traditional and modern, and more than half (52%) describe it as boring. The majority of participants (53.4%) express that the facade appears ordinary, neglected, and dirty (Fig. 8).

The participants were briefly informed about Corten, the facade material of Şimal Shopping Mall. This

information is as follows: The facade material of Şimal Shopping Mall is Corten. This material is a steel material made resistant to atmospheric corrosion. The colour of the material changes from orange to dark brown in an average of 40 years. The participants were asked what the changing colour of the facade of Şimal Shopping Mall means to them. The answers given by the participants were grouped. These responses were categorized into three groups under the headings: physical, environmental, and emotional. The majority of those who physically evaluated the change in the colour of the facade material described the facade as no different from a rusted iron (27 participants); ugly (19 participants), old-neglected (10 participants) and polluting (5 participants). Among those who evaluate the colour change from an environmental point of view, there



Figure 9.

User opinions about color change in terms of physical, environmental and emotional aspects [Source: Authors]



Figure 10.

User opinions about color change in terms of physical, environmental and emotional aspects [Source: Authors]

are those who state that it is an indicator of vitality (4 participants) and naturalness (3 participants), as well as those who state that it is incompatible with the environment (3 participants) and creates an unhealthy image. Those who expressed their emotional opinions about the colour change were those who found it interesting (13 participants) and thought it would be a good change (8 participants), as well as those who thought it was ridiculous (10 participants) and unnecessary (6 participants). Approximately 10% of the individuals surveyed showed no interest in the subject, saying that they had no feeling that the Corten material would change colour with the rust layer over the years (Fig. 9).

The participants were given information about the colour and properties of Corten, the facade material of Şimal Shopping Mall. This information is as follows: Corten, which covers the facade of Şimal Shopping Mall, is a corroded steel. This layer protects the material against external weather conditions. After the information, the participants were asked what it means to them that the Corten material will continue to rust. The answers given by the participants were grouped under three headings as physical, environmental and emotional in terms of their content. In terms of the physical aspect of the Corten steel will continue to rust, the most (47 participants) stated that there will be a rusted appearance. In addition, it was reported that rusting cre-

ates a physically bad (33 participants) and dirty (14 participants) perception, absurd (7 participants) and disturbing (7 participants). Most of those who expressed environmental views on rusting (8 participants) stated that this situation is unhealthy, but economically (3 participants) and ecologically (3 participants) environmentally friendly, healthy and sustainable. Those who expressed their views on this situation from an emotional point of view said that it was both upsetting (3 participants) and interesting (3 participants), and that it led to negative thoughts (anxious, insecure, frightening, surprising) emotionally. Some of the participants also stated that the fact that rusting will continue over time does not mean anything (Fig. 10).

4. DISCUSSIONS AND CONCLUSIONS

Corten steel is a material that offers numerous advantages in terms of sustainability. While the initial construction cost of Corten is high, it proves to be an economical building material over the life cycle of the structure as it does not require maintenance and painting afterward. From an environmental perspective, its lack of CO₂ emissions and 100% recyclability demonstrate its environmental sensitivity. Furthermore, its corrosion resistance and excellent mechanical properties support its use as an exterior facade element, structural support, and decorative element in the field of architecture. The study reveals

how Corten steel, with its significant and versatile qualities, is perceived by users.

The users stated that, although Corten steel is interesting because it will change color and has durability behind its rusty appearance, they would prefer to use a material that is more suitable for Rize province, such as wood. While the dark color of the material was generally criticized, the use of lighter colors such as blue and green was suggested. Even though awareness is created for the material, many people stated that it would be right to use a more attractive material for the shopping centre. However, the continuation of the oxidation process and the change of the material were perceived by many people as naturalness and the continuation of the life of a living organism. Even if the material leaves positive thoughts, it was emphasized that it is incompatible with the environment. In addition, many people reacted by thinking that they should wait for 40 years for color change.

Although Corten steel is an environmentally friendly material, it creates a negative perception in terms of appearance. However, since Corten is a sustainable material, there are users who support its use in economic and ecological terms. These users have suggested ideas such as revitalizing the facade surface with lighting to create a more positive perception of the facade color. The fact that Şimal Shopping Mall is located in Rize province, known as the city with the highest rainfall in the country, supports the idea that the rusting of hollow steel will gradually increase. It also creates the perception that the gradual increase in rusting will reduce the durability of the material. Some express concerns that the holes on the Corten, forming a pattern, may disturb people with tryphobia, which is called hole phobia.

In conclusion, Corten steel is a material with positive aspects in terms of economic and environmental sustainability. Its sustainability contributes to a positive perception among users. The fact that the material has received a generally negative reaction is a situation anticipated by the designers. In this sense, the current color of the material, the prospect of color change throughout its life cycle, its rusty appearance, and texture contribute to a negative perception of the building facade. However, after presenting information about the sustainable properties of the material, these negative opinions have significantly decreased. The project, intended by the designers to be a symbolic structure as the first shopping mall of the city, asserts itself as an iconic design with its Corten steel facade in the residential area. For a sustainable envi-

ronment and world, Corten steel should be promoted for increased preference among materials used in building production.

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REFERENCES

- [1] Rodriguez Pinto, P.J. (2022). Design of a Corten steel pedestrian bridge in Piedicavallo (Biella), with the use of the BIM Methodology, PhD, Politecnico di Torino.
- [2] Albrecht, P., & Naeemi, A.H. (1984). NCHRP Report 272: Performance of Weathering Steel in Bridges, WASHINGTON, D.C.
- [3] Es, K.C., & Girgin, Z.C. (2017). Cephe Malzemesi Olarak Atmosferik Korozyona Dayanıklı Çelikler ve Dayanıklılığa Etki Eden Faktörler. [Factors Affecting Weathering Steel Durability As Facade Material] *AURUM Journal of Engineering Systems and Architecture*, 1(2), 109–120.
- [4] Bupesh Raja, V.K., Palanikumar, K., Rohith Renish, R., Ganesh Babu, A.N., Varma, J., & Gopal, P. (2021). Corrosion resistance of corten steel – A review. *Materials Today: Proceedings*, 46 3572–3577. <https://doi.org/10.1016/j.matpr.2021.01.334>.
- [5] Reddy, M.S., Kumar, G.V.S., Bhaskar, T., & Sivaprasad, K. (2023). Mechanical Behaviour, Microstructure and Texture Studies of Wire arc Additive Manufactured Corten Steels. *Transactions of the Indian Institute of Metals*, 76(2), 519–526. <https://doi.org/10.1007/s12666-022-02725-z>.
- [6] Aramendia, J., Gomez Nubla, L., Castro, K., Martinez Arkarazo, I., Vega, D., Sanz López de Heredia, A., García Ibáñez de Opakua, A., & Madariaga, J.M. (2012). Portable Raman study on the conservation state of four CorTen steel based sculptures by Eduardo Chillida impacted by urban atmospheres. *Journal of Raman Spectroscopy*, 43(8), 1111–1117. <https://doi.org/10.1002/jrs.3158>.
- [7] Castro, K., Aramendia, J., Gomez-Nubla, L., Vega, D., López de Heredia, A., & Ibáñez de Opakua, A. (2011). The Conservation of Weathering Steel Sculptures, a Comparative Study of Chillida's Sculptures Exposed in Bilbao, *Int. Conf. on Non-Destructive Investigations and Microanalysis for the Diagnostics and Conservation of Cultural and Environmental Heritage (ART 2011)*, 13-15 April 2011, Florence, Italy.

- [8] Nippon Steel Corporation. (2023). Nippon Steel COR-TEN. Retrieved from https://www.nipponsteel.com/product/catalog_download/pdf/A006en.pdf (accessed 13 July 2023).
- [9] Yüzer, M. (2022). Mimari sürdürülebilirlik kavramı açısından yapılarda corten çelik kullanımı: Troya Müzesi örneği. [The use of corten steel in buildings in terms of the concept of architectural sustainability: the example of Troy Museum] Master of Science, Bursa Uludağ University.
- [10] Kim, S., & Kwon, H. (2018). Urban Sustainability through Public Architecture. *Sustainability*, 10(4), 1249. <https://doi.org/10.3390/su10041249>.
- [11] Damian, L., & Fako, R. (2000). Weathering structural steels corrosion in atmospheres of various degrees of pollution in Romania. *Materials and Corrosion*, 51(8), 574–578. [https://doi.org/10.1002/1521-4176\(200008\)51:8<574::AID-MACO574>3.0.CO;2-0](https://doi.org/10.1002/1521-4176(200008)51:8<574::AID-MACO574>3.0.CO;2-0).
- [12] Deepak, J.R., Raja, V.B., Basha, M.R., & Kumar, M.G.D. (2019). Improvement of weldment by post weld heat treatment of low carbon steel. *International Journal of Mechanical and Production Engineering Research and Development*, 9, 1249–1256.
- [13] Marchwiński, J. (2019). *Stal w architekturze. BUILDER*, 258(1), 18–22. <https://doi.org/10.5604/01.3001.0013.3330>.
- [14] Targowski, W., & Kulowski, A. (2021). Influence of the Widespread Use of Corten Plate on the Acoustics of the European Solidarity Centre Building in Gdańsk. *Buildings*, 11(3), 133. <https://doi.org/10.3390/buildings11030133>.
- [15] Targowski, W., (2018). Gmach Europejskiego Centrum Solidarności – geneza przestrzeni, w poszukiwaniu tożsamości miejsca, in: K. Knoch et al. (red.) (Ed.), *Historia Stoczni Gdańskiej, Biblioteka ECS, Gdańsk*, pp. 661–679.
- [16] Valletta, E., & Camiz, A. (2019). Image reintegration. Restoring the Palace in the Kyrenia Castle, Cyprus, ReUSO Matera, VII Convegno Internazionale, 23-26 Ottobre, Patrimonio in Divenire, Conoscere, Valorizzare, Abitare, pp. 2241–2250.
- [17] Kasso Engineering. (2023). Cor-ten Çelik Malzemeler. [Cor-ten Steel Materials] Retrieved from <https://www.kasso.com.tr/cor-ten-celik-malzemeler> (accessed 30 September 2023).
- [18] Casaletto, M.P., Figà, V., Privitera, A., Bruno, M., Napolitano, A., & Piacente, S. (2018). Inhibition of Cor-Ten steel corrosion by “green” extracts of *Brassica campestris*. *Corrosion Science*, 136, 91–105. <https://doi.org/10.1016/j.corsci.2018.02.059>.
- [19] Kumaravel, D., Bupesh Raja, V.K., Balthaser, K., Jayaganthan, A., Sahas, S., Muralidharan, S., & Achameleh, T. (2022). Investigation on Wear and Corrosion Behavior of Cu, Zn, and Ni Coated Corten Steel. *Advances in Materials Science and Engineering*, 2022 1–9. <https://doi.org/10.1155/2022/7341201>.
- [20] Nagaraj, S., & Kumaresh Babu, S.P. (2020). Protective polyurea coating for enhanced corrosion resistance of sole bars in railway coaches. *Materials Today: Proceedings*, 27 2407–2411. <https://doi.org/10.1016/j.matpr.2019.09.152>.
- [21] Xu, Q., Gao, K., Lv, W., & Pang, X. (2016). Effects of alloyed Cr and Cu on the corrosion behavior of low-alloy steel in a simulated groundwater solution. *Corrosion Science*, 102 114–124. <https://doi.org/10.1016/j.corsci.2015.09.025>.
- [22] Sharma, V., Sharma, J.K., Kumar, S., & Panwar, S. (2019). 3001 Published By: Blue Eyes Intelligence Engineering & Sciences Publication Retrieval Number: B8113129219/2019@BEIESP DOI: 10.35940/ijitee.B8113.129219 Journal Website: www.ijitee.org Age Hardening in COR-Ten Steel. *International Journal of Innovative Technology and Exploring Engineering*, 9(2), 3001–3004. <https://doi.org/10.35940/ijitee.B8113.129219>.
- [23] Halilović, A.E., Faleskog, J., Boåsen, M., & Efsing, P. (2021). An experimental-numerical screening method for assessing environmentally assisted degradation in high strength steels. *Engineering Fracture Mechanics*, 245, 107572. <https://doi.org/10.1016/j.engfracmech.2021.107572>.
- [24] Deepak, J.R., Bupesh Raja, V.K., Srikanth, D., Surendran, H., & Nickolas, M.M. (2021). Non-destructive testing (NDT) techniques for low carbon steel welded joints: A review and experimental study. *Materials Today: Proceedings*, 44, 3732–3737. <https://doi.org/10.1016/j.matpr.2020.11.578>.
- [25] Agkathidis, A. (2019). Dark Matter Garden: A case study in algorithmic modelling and digital fabrication of complex steel structures. *Frontiers of Architectural Research*, 8(3), 303–310. <https://doi.org/10.1016/j.foar.2019.05.003>.
- [26] Buchanan, C.A., Charara, M., Sullivan, J.L., Lewis, G.M., & Keoleian, G.A. (2018). Lightweighting shipping containers: Life cycle impacts on multimodal freight transportation. *Transportation Research Part D: Transport and Environment*, 62, 418–432. <https://doi.org/10.1016/j.trd.2018.03.011>.
- [27] Müller, A., Österlund, H., Nordqvist, K., Marsalek, J., & Viklander, M. (2019). Building surface materials as sources of micropollutants in building runoff: A pilot study. *Science of The Total Environment*, 680, 190–197. <https://doi.org/10.1016/j.scitotenv.2019.05.088>.
- [28] Satola, D., Kristiansen, A.B., Houlihan-Wiberg, A., Gustavsen, A., Ma, T., & Wang, R.Z. (2020). Comparative life cycle assessment of various energy efficiency designs of a container-based housing unit in China: A case study. *Building and Environment*, 186, 107358. <https://doi.org/10.1016/j.buildenv.2020.107358>.

- [29] Di Ruocco, G., Sicignano, C., & Sessa, A. (2017). Integrated Methodologies Energy Efficiency of Historic Buildings. *Procedia Engineering*, 180, 1653–1663. <https://doi.org/10.1016/j.proeng.2017.04.328>.
- [30] Guerriero, L., Cicala, M., Chiacchio, N., & Tomeo, M. (2018). Analysis of the restoration and consolidation of the late baroque church of Spirito Santo in Aversa. *Procedia Structural Integrity*, 11, 379–387. <https://doi.org/10.1016/j.prostr.2018.11.049>.
- [31] Wilczek, I. (2021). The layers of history: New architecture interventions in castle ruins. *Frontiers of Architectural Research*, 10(2), 351–368. <https://doi.org/10.1016/j.foar.2020.12.001>.
- [32] Kunawong, M. (2019). *Temporality Dimensions in Architecture: The intervention of time perception*, Master of Science, Cornell University.
- [33] Koday, Z., & Erhan, K. (2013). Rize İlinin İdari Cođrafya Analizi. [Administrative Geographic Analysis of Rize Province] *Atatürk Üniversitesi Sosyal Bilimler Dergisi*, (50), 39–54.
- [34] Polat, P., & Sunkar, M. (2017). Rize'nin İklim Özellikleri ve Rize Çevresinde Uzun Dönem Sıcaklık ve Yağış Verilerinin Trend Analizleri. [Climate Characteristics of Rize and Trend Analysis of Long-Term Temperature and Precipitation Data Around Rize] *Fırat Üniversitesi Sosyal Bilimler Dergisi*, 27(1), 1–24. <https://doi.org/10.18069/firatsbed.346684>.
- [35] İki Design Group. (2023). Rize Mixed Use Project. Retrieved from <https://www.ikidg.com/projects/rize-mixed-use-project> (accessed 30 September 2023).