Environmental Aspects of the Use of Construction Materials from Thin-Sheet Galvanized Steel in the Far Eastern Federal District

V E Pasichnikov¹, L P Mayorova²

¹Post-graduate student of the Department of Ecology, Resource Use and Life Safety, Pacific State University (PNU), Khabarovsk, Russian Federation
²Doctor of Chemistry, Associate Professor, Head of the Department of Ecology, Resource Use and Life Safety, Pacific State University (PNU), Khabarovsk, Russian Federation

E-mail: hiver91@mail.ru

Abstract. The main environmental benefits for the selection of the thin-sheet galvanized steel in the production of construction materials that meet the requirements of sustainable construction are reasoned. The analysis of the material life cycle is presented. The advantages of products from the thin-sheet galvanized steel in comparison with alternative materials of similar purpose are described as well. The comparative analysis presents the regional aspect of the use of construction materials.

1. Introduction

Construction work (construction production) are itself an environmental burden. When designing venues for various purposes, engineers take into account a number of factors affecting the choice of construction materials, such as: estimated cost, quality characteristics, country of origin and brand, functionality, service life, environmental friendliness, availability of certificates, appearance, expert opinions, advertising and logistics.

Although "Sustainability" is taken into account only as one of the factors, it influences each one of them to one degree or another. Therefore, this key factor should be particularly considered. The importance of this factor began to increase with the development of the Internet and the craze for “eco-products”. The construction industry, in its turn, has responded with the widespread adoption of these green standards.

Abroad, a methodological base of construction production standards has been formed within the framework of sustainable development. There is a practice of using rating systems for buildings and structures. The main ones are the LEED, BREEAM and DGNB ecological systems, which allow assessing the versatile aspects of construction.

Furthermore, the LCA (Life Cycle Assessment) system, which is widely used in all areas of goods production, has been applied in the construction industry. LCA is a parameter for assessing the sustainability of a project, which allows to obtain information about scenarios and stages of the life cycle. The requirements of the Life Cycle Assessment method are described in the ISO/DIN 14040 standard.
The applied software systems and algorithms make it possible to predict up to 50 years of building operation. This technique allows to make smart decisions that imply the greatest savings when it comes to operation of buildings. From the viewpoint of a life cycle, it is truly worth considering the environmental benefits of the thin-sheet galvanized steel materials. [12]

2. **The overview of construction materials**

In the construction industry, there is a wide range of materials that involve thin-sheet galvanized steel. The main types are:

- Facade: metal siding; wall corrugated board; facade cassettes, etc. ;
- Roofing: metal tiles; folded roof; roofing sheeting, etc. ;
- Drainage systems;
- Fences and barriers;
- Additional elements.

It is used in all sectors, from low-rise individual construction to the construction of large industrial and social and cultural facilities. In view of the significant historical retrospective of use, the material (roofing iron) is used for the restoration of architectural monuments. [3] [4]

3. **Regional features of application in the Far Eastern Federal District**

When it comes to a comprehensive assessment of construction materials, one should not forget about regional peculiarities. Due to the fact that the main metal producers are located in slightly remote locations, manufacturing plants located in in the midlands, the west of Russia (MMK; NLMK; Severstal) and the Far Eastern Federal District are forced to purchase metal in the neighboring PRC. At the same time, the systems of environmental and production quality management, quite often do not meet the requirements enforced in our country. Therefore, over the past ten years, a significant decrease in the quality of materials can be traced, which is manifested in such characteristics as: metal thickness, quantitative composition of zinc per square centimeter of the product, quality of polymer and paintwork of materials. Moreover, the vast majority of companies producing goods from sheet metal do not have metrological laboratories and do not assess the quality of incoming raw materials. Nevertheless, the metal that comes from the PRC has one indisputable advantage - the price. Against the background of a sharp drop in the solvency of the residents of the Far East, the metal produced in the Russian Federation, having obvious qualitative advantages, is in little demand.

According to GOST 24045—2016, the mass of zinc coating applied to 1 m2 on both sides of the sheet should be equal to 414 g; however, in order to diversify the assortment, manufacturers produce a sheet in which the mass of zinc coating per m2 drops down to 80 g. As a result, the product is made out of low quality metal and has a significantly shorter service life. First of all, the protective paint and varnish and polymer coating suffers, bringing the elements of structures to an inappropriate condition from an aesthetic point of view. Building owners have to renew the material multiple times, which is a significant environmental burden already. In general, lighter carbon footprint and a decrease in the material costs, due to a cut in the logistics, is clearly a plus in assessing the environmental aspects of the use of thin-sheet metal in the Far Eastern Federal District. However, manufacturers of construction materials need to create a system of qualitative assessment of the purchased raw materials – the thin sheet-galvanized steel in coils.

4. **Methodology for the environmental assessment of construction materials by the life cycle**

In order to justify the choice of construction materials based on the principle of superior environmental performance, it is necessary to conduct a comparative analysis with alternative materials that have similar purpose. Based on the main areas of application of construction materials made out of thin-sheet galvanized steel, the following are presented as the alternatives:

- Facade: products made of Polyvinylchloride (PVC) * - Vinyl siding; composite material based on a polymer composition reinforced with an aluminum protective layer (Composite) * - Aluminum composite panels.
• Roofing: materials based on bitumen - "Bikrost", "Ruflex" (Bitumen); chrysotile-cement products (Asbestos) * - Slate.
• Drainage systems: products made of Polyvinylchloride (PVC) * - Plastic drain "Grand Line".
• Fences: chrysotile-cement products (Asbestos) * - Asbestos-cement sheet.

* the main components of materials that affect the environment are highlighted in brackets.

A preliminary environmental assessment of the load of construction materials on the environment will be carried out on the basis of the methodology developed by prof. Knyazeva V.P. [6]. This methodology distinguishes the 5 stages of the life cycle:

- extraction of raw materials;
- manufacturing of materials and products;
- construction phase;
- exploitation;
- destruction or reuse.

Analysis of the environmental load of materials by the groups of components is presented in Table 1.

**Table 1.** Environmental assessment of the impact on the environment and humans, the main components used for the manufacturing the construction materials.

| Type of CM | Negative effects of the CM in accordance with the Life Cycle | EI value |
|------------|------------------------------------------------------------|----------|
|            | Environmental damage | Scarcity | Emission | Energy | Health | Waste | Total |
| Construction materials for facades, roofs, drainage systems and fences | | | | | | | |
| Metal      | 3                | 3        | 1        | 3      | 2      | 1      | 13    |
| PVC        | 3                | 3        | 3        | 3      | 2      | 2      | 16    |
| Composite  | 3                | 3        | 2        | 3      | 3      | 3      | 17    |
| Bitumen    | 3                | 3        | 3        | 3      | 3      | 3      | 18    |
| Asbestos   | 3                | 3        | 3        | 3      | 3      | 3      | 18    |

**Damage to the ecosystem:** It is assessed what impact on the environment, at all stages of the life cycle, each type of building materials has. Each of these species is expected to have a significant impact.

**Scarcity:** This criterion evaluates the replenishment of natural components in terms of the production of materials from primary resources. Stocks of all types of raw materials are depleted, so their use can lead to their shortage, causing significant damage.

**Emissions:** During the use of materials, under the influence of various atmospheric and technogenic factors, the release of pollutants may occur.

**Energy:** Energy consumption for the extraction, transportation and production of construction materials from primary components. In all cases presented, they cause significant damage to the environment.

**Health:** Assessment of the direct impact of the main components of the material on human health at all stages of the life cycle.

**Waste:** The development of the waste turnover system (transportation, storage, concentration, neutralization, dumping) forms an estimate for this parameter.

Thus, the total load on the environment in accordance with the six listed "environmental factors" for various construction material, ranges from 13 to 18 points.
Table 2. Scale of the total load on the environment and humans for the analyzed materials.

| Low influence | Average influence | High influence |
|---------------|-------------------|---------------|
| 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 |

Based on the scale of the total load, it can be stated that all analyzed building materials belong to the group of high environmental load. The main points are scored in the columns "Environmental Damage", "Scarcity" and "Energy" due to the fact that production technologies, as well as production processes in our country, are associated with high levels of emissions, in all industries. However, at the moment there are no alternative options for materials that could be used in mass construction, it is necessary to conduct a more detailed analysis of the life cycle of products based on the materials considered.

5. Detailed analysis of the life cycle

In order to substantiate the environmental benefits of the thin-sheet metal as a construction material, it is necessary to identify and evaluate the main stages of its life cycle:

1. **Raw materials:** Recycled scrap metal. The possibility of using recycled products as raw materials for the production is one of the main aspects of the product's environmental friendliness. Given the fact that the final products are almost entirely made of metal, this allows us to call such building materials fully recyclable. Also, comparing the technological processes of recycling and transportation of alternative building materials (vinyl siding; fused roofing materials based on bitumen; ACP), the remelting of scrap metal has the lowest emission of toxic compounds. At the same time, technological processes are constantly being improved to reduce the environmental burden.

2. **Production of rolled metal:** Production complexes introduce the best available technologies to reduce the technogenic impact on the environment. Magnitogorsk Iron and Steel Works LLC was awarded a diploma from the United Nations Industrial Development Organization (UNIDO) for its contribution to sustainable development and environmental initiatives in the Chelyabinsk region. In 2000-2018, the plant allocated more than 58 billion rubles for environmental protection, and by 2025 intends to invest more than 38 billion rubles in improving the environmental situation, including 21.7 billion rubles in air protection measures. [7]

3. **Packing:** There are two types of packaging: 1. Galvanized steel sheets formed in a bundle, stacking one sheet on top of another. 2. Rolls of galvanized steel rolled onto a thick paperboard core. Packs and rolls should be tightly tied with metal tape 1.2-2.0 mm thick, 30-40 mm wide. The packaging is minimal and also 100% recyclable, which is an undoubted plus in the direction of environmental friendliness of the material. [8] [9] [10]

4. **Logistics:** Of all the stages of the life cycle, logistics is the weakest. Due to the high mass of packs or rolls, transportation of this type of product consumes a significant fuel resource, accompanied by emissions. The packaging is designed to minimize economic and environmental costs. Analyzing the logistics of supplying material to the Far East, the purchase of products from factories in the northeast of China is more profitable in terms of transportational environmental load. At the same time, from the point of view of the quality of the supplied materials, there are issues that affect the environmental reliability.

5. **Manufacturing:** Manufacturers of equipment for processing sheet metal mindfully perceive the concept of environmental responsibility and reinforce the corresponding innovative principles in technological processes. Among these is the AMADA concern. The AMADA servo-electric drive combines the advantages of traditional mechanical drives with the responsiveness of high-power hydraulic drives. The innovation of the control system lies in the fact that during braking or deceleration of the drive, the machine switches to the generator mode and accumulates the generated energy.
6. **Operation (Construction production):** The environmental load in the process of installing products from sheet metal is based on the energy consumption of hand-held power tools, as well as waste of the material itself, which in its turn is completely recyclable. The hardware used for fastening products in their bulk is made of various types of metals, also completely recycled, which allows them not to be separated from the bulk of construction waste.

The service life of construction materials made of thin-sheet metal without major repairs directly depends on the quality of the metal itself, as well as protective layers of zinc or polymer compounds. Subject to GOST, the standard service life of the products is 20 - 30 years, in comparison to the roofing materials based on petroleum products that can be used for no more than 12 years, and for PVC materials - is 3-5 years. Emissions of toxic substances during the operation of these materials are so small that they can be neglected. [12] [13]

7. **Disposal:** The infrastructure for the recycling construction materials from sheet metal is directly related to the first one, which speaks of complete recycling and is one of the main factors in the use of material in the production of works that meet the principles of eco-friendly construction.

6. **Environmental aspects of using alternative construction materials**

6.1. **Polyvinyl chloride and polymer composition**

The binders in vinyl siding are susceptible to UV light and oxidation. Vinyl is the most hazardous in production and disposal. Vinyl in a landfill can pose a threat to groundwater due to the release of dioxins and other toxins as the material degrades. [14] [15]

Gross CO2 emissions for plastics production are around 1.3, 1.4 and 1.7 kgCO2/kg of PE, PP and PVC, respectively. CO2 emissions for electricity used for PVC production were higher than for polyethylene and polypropylene, as electrolysis for chlorine production requires additional electricity.

Taking into account the regional specifics of the use of the material on the territory of the Far Eastern Federal District, where the average January temperatures are from -20 ° to -32 °, with an average weight of the snow cover equal to 2.4 kPa/m2, it is necessary to take into account the instability of PVC products and polymer composition when it comes loads.

Most plastics show their usual properties of flexibility (low Young's modulus) and high resistance to cracking at room temperature, but these properties change rapidly as the temperature drops. Many types of plastics become brittle at low fracture stresses. The polyvinyl chloride molecules and polymer composition begin to act as hard and glassy solids below the glass transition temperature. Impact resistance is significantly reduced and increased brittleness at low impact energy becomes the main cause of decay.

If the choice of materials does not take into account the low-temperature properties of plastics, this leads to catastrophic consequences, turning the construction material into waste, long before the end of the standard life cycle.

6.2. **Bitumen**

The distillation of crude petroleum oils, which give significant amounts of heavy residues, usually 10 to 50%, although sometimes crude oils are used, giving higher residue yields. During the production of fusion roofs, particulate matter emissions, including bituminous smoke, were 1.35 mg/g bitumen for controlled conditions and 3.15 mg/g bitumen for uncontrolled conditions. Bitumen emissions are defined as complex mixtures of aerosols, vapors and gases from heated bitumen, and products that contain bitumen.

In a US study, 26 workers involved in removing old roofs, installing new roofs were tested to assess the effects of polyaromatic hydrocarbons (PAHs) on skin. Cutaneous PAH concentrations were about four times higher than normal in workers tearing off old roof covering. These concentrations were 2–20 times higher than those recorded for road surfaces. Exposure to coal tar was associated with a 35-fold increase in skin exposure to benzo [a] pyrene. [16] [17]
6.3. Asbestos
Impossibility of using recycled raw materials. As a result, there is a high environmental load during mining. The production process is associated not only with the load on the ecosystem of the adjacent territories, but a negative impact on human health has been proven. Asbestos is a known carcinogen, and inhalation of asbestos fibers causes breathing problems and lung diseases such as asbestosis, mesothelioma, or lung cancer. All three of these diseases experience delayed development, and these diseases may not appear until 10-40 years after the initial exposure to asbestos. Asbestos that is intact, intact, and in good condition does not necessarily pose a health problem. Deterioration and damage is caused by fibers released into the air. To remove or repair asbestos-containing materials that are damaged or will be disturbed during the construction process, it is imperative that special methods are taken and special methods are applied. [18] [19] [20]

7. Conclusions
In the considered material selection range, galvanized sheet steel is presented as a material that has a minimal impact on the environment. For each stage of the life cycle, there are aspects of an obvious advantage over alternative materials. This material, as subject to the rules of safety and labor protection, is absolutely safe for humans, at all stages of the life cycle. The standard life cycle, subject to manufacturing and construction technologies, is one of the highest. The requirements for the quality of galvanized sheet steel in our country are very high and highly rated all over the world, which allows us to speak about the durability of the material. This can also be traced back to the historical perspectives, in contrast to newly created materials that have not yet passed the test of time. Galvanized sheet steel is a multifunctional material. Galvanized sheet steel is a multifunctional material. At some sites, the entire range of construction work on the installation of the roof, facade, drainage systems, as well as permanent and temporary fences, can be made exclusively from this material. Ease of installation, due to the use of hand tools, the introduction of innovative principles in technological processes, reduces the consumption of electricity from the network and allows this material to be considered energy-saving. The ability to use renewable raw materials for production, in the form of ferrous scrap, speaks of a resource-saving component. A high degree of maintainability and utility is another indisputable plus in the ecological "piggy bank" of this material. Ease of sorting the dismantled material, all of its components and related components, creates favorable conditions for complete recycling. The rich color gamut of the material grants architects and designers the widest range of its applications; all in accordance with the principles of video ecology.

Taking into account the set of methods for analyzing the main components of construction materials that have an impact on the environment, it can be concluded that the metal in general, and for the group of materials under consideration, in particular, the thin-sheet galvanized metal, is the most beneficial from an environmental point of view.

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