ENGINEERING AND ECOLOGICAL METHODS FOR PROTECTION AGAINST CATASTROPHIC NATURAL PROCESSES CAUSED BY GLOBAL CLIMATE CHANGE

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Abstract

The paper discusses issues related to global climate change. It's identified that climate change is associated with global warming, caused by a sharp increase in the concentration of greenhouse gases in the atmosphere. Climate warming is accompanied by intense snowmelt and water evaporation. The cloud cover that accumulates in the atmosphere contains a tremendous amount of water, which falls as prolonged heavy rainfall, leading to catastrophic floods accompanied by mudflows, landslides, and erosion processes. The authors developed simple, reliable, and relatively inexpensive protective structures used during floods, mudflows, and landslides. Additionally, new designs for coastal protection were developed. The construction of these structures utilizes waste materials such as recycled tires and reinforced concrete sleepers.

Keywords: engineering-ecological, method, protection, disaster, global, climate, atmosphere, water, waste, warming, coastal protection, flood, mudflow

I. Introduction

Global climate change has become a major scientific and political issue only in recent decades. Politicians around the world often avoid analyzing survey results that indicate growing public concern. Scientific journals are overloaded with publications on this topic, analyses, and commentaries.

In May 1990, climatologists from around the world, in a report for the Intergovernmental Panel on Climate Change (IPCC) established in 1988 by the UN General Assembly to draw the attention of world leaders to the serious problems of global climate change, stated it very clearly. "We are confident," said more than 300 scientists from over twenty countries, "that emissions into the atmosphere caused by human activity are leading to a significant increase in the concentration of greenhouse gases in the atmosphere. This increase in carbon dioxide concentration enhances the greenhouse effect, resulting in additional warming of the Earth's surface.

Even 25 years ago, scientists had predicted, based on climate computer models, an average temperature increase of about 1°C over thirty years if the rate of greenhouse gas emissions in the atmosphere remained at the levels existing at the end of the last century. An increase of one degree may not seem significant, but this is an average across the entire globe, where temperatures have never risen this quickly based on paleoclimatic data. In less than half a century—if current trends continue - we will face temperatures unprecedented since humanity has existed on the planet.

At that time, the scientists and IPCC experts stated that their estimates were likely to be somewhat understated: the number of uncertainties inevitably present in climate change calculations is immense; and warming is likely to be exacerbated by a series of natural processes.

If the current trend continues, by 2030-2050, the atmosphere will contain a quantity of greenhouse gases that will have a heat-absorbing capacity twice that of the carbon dioxide present in the atmosphere in the mid-twentieth century.

It should be expected that global warming will continue indefinitely unless actively mitigated by the efforts of the human community.

No one can predict with certainty what changes will occur in ocean currents or how the climate will change in any specific location on Earth with the disappearance of Arctic ice.

II. Main Causes and Forecast of Further Climate Warming on the Planet

The reasons for the accumulation of greenhouse gases are not as well defined as is often claimed. The primary cause is industry, which relies on fossil fuels as an energy source. Deforestation is also responsible, as it can lead to a significant increase in carbon dioxide concentration in the atmosphere if remaining forests are systematically destroyed. Additionally, there has been a sharp increase in forest fires, often caused by criminal elements for personal profit. A third source of carbon dioxide in the atmosphere is the decomposition of organic matter in the soil due to warming.

Warming on Earth will occur through physical, chemical, and biological processes at both local and global scales. The central question is whether the quantitative effects of these changes will lead to rapid or slow warming. Negative feedback will reduce the rate of warming if it starts to occur more intensely, while positive feedback will amplify it. Such feedbacks can involve changes in cloud cover or snow cover, as they affect the Earth's surface albedo and, consequently, the amount of energy absorbed. An increase in snow or cloud cover will raise the albedo, reduce the amount of solar energy retained, and decrease the warming process, creating negative feedback. A decrease in the Earth's surface albedo works in the opposite direction, creating positive feedback. These changes were taken into account by climatologists when they conducted quantitative assessments of warming.

Cities, hydroelectric stations, irrigation systems, navigation, changes in waterways, transport, marine life, fishing, and oceanic and coastal water circulation all depend on the freshwater flows that are formed.

Forecasts of changes in surface runoff are unreliable, as are other potential consequences of warming on Earth. Within a narrow range of 1°C to 2°C of overall warming, the general picture seems clear. Beyond this range, the consequences of warming become uncertain. Meanwhile, long-term costly projects require further forecasting of precipitation, the results of which become dubious.

According to forecasts from the second working group of the IPCC, large-scale flooding may occur, for example, in many rivers of Western Europe and the northern rivers of Russia.

IPCC specialists, based on climate models, concluded that if measures are not taken to halt greenhouse gas emissions, sea levels could rise by 10-30 cm by 2030 and by 30-100 cm by the end of the current century. This increase will result from the expansion of seawater due to warming and the melting of glaciers. It is assumed that the effects of melting Greenland and Antarctic ice sheets will be minimal during this century. Other scientists believe that the melting of Antarctic ice will lead to a sea-level rise of more than 5 meters. These analyses are only hypothetical, and local effects may be more significant depending on whether the continental plates in a given area are rising or sinking.

III. Intensification of Catastrophic Processes Due to Global Climate Warming

Since the late 20th century, the frequency of floods has increased, as have the damages caused by them. Currently, the area prone to flooding exceeds 3 million km², home to 1 billion people.

Thousands die from floods each year, with annual losses amounting to tens of billions of US dollars. Floods lead to diseases, famine, and numerous ecological problems.

Global climate warming is accompanied by intense snowmelt and water evaporation. The accumulated cloud cover in the atmosphere contains vast amounts of water, which falls as prolonged heavy rainfall, creating catastrophic floods along with mudflows, landslides, and erosion processes.

Due to sharp warming, glacial mudflows caused by intensified glacier melting have become more frequent. These glacial mudflows result from the bursting of subglacial lakes and reservoirs, and they almost always have catastrophic consequences

There is a need to develop economically and ecologically efficient engineering measures to prevent or at least significantly reduce the damage from the increasing catastrophic events caused by global climate changes.

The intensity of glacier melting in mountainous regions, driven by global warming, has led to the emergence of numerous glacial lakes. Recent studies have identified over 2,300 glacial lakes in Nepal and Bhutan, of which 20 have been classified as high-risk for bursting [1].

Global warming has sharply increased the incidence of major floods, inundations, and mudflow processes. These processes intensify erosion, the destruction of riverbanks, lakes, and seas, as well as landslide phenomena.

The aforementioned issues highlight the need for effective engineering methods for flood protection, bank erosion control, mudflows, landslides, and other catastrophic and emergency events. There is significant interest in using recycled waste materials in the construction of protective structures.

IV. On the Use of Recycled Tires in the Construction of Protective Structures Against Catastrophic Natural Phenomena

The most common type of consumer waste is recycled automobile and tractor tires. Globally, half of all synthetic and natural rubber produced (over 15 million tons annually) is used for tire manufacturing, and ultimately all produced tires become waste after a certain period. The lifespan of automobile and tractor tires is shorter than that of most rubber products [2].

The authors have developed simple and relatively inexpensive protective structures using recycled steel-belted tires for use during floods. A filtering dam, constructed on the tributaries of major rivers, can create a temporary reservoir in flood zones and is laid across the tributary channel in the form of a trapezoidal prism. The dam is made of cylindrical gabions filled with soil. The shells of the cylindrical gabions are made from interconnected recycled steel-belted tires of the same type. The gabions are laid in layers along the tributary channel, alternating layers with longitudinal and transverse orientations relative to the flow. Longitudinal rows of gabions are spaced apart. This construction allows for the building of protective dams in riverbeds of any configuration and in any geological conditions with minimal material costs.

The authors have also developed a flood protection dam to safeguard populated areas, agricultural, and industrial facilities from flooding. This dam includes interconnected cells with vertical flexible walls made from outer and inner shells. Recycled steel-belted tires of the same type are used as shells, connected by various fastening elements (metal or polymer). The cavity formed by the tires is filled with ballast material (local soil). The shells are reinforced with cross-members made of flexible impermeable material. The upper cross-members are connected by tensioning to anchors, designed as screw piles or braces. The feasibility of using this flood protection dam is due to the increased efficiency of a lightweight structure that can be installed and reinstalled multiple times at various locations with minimal labor costs.

Numerous designs of mudflow protection structures using recycled tires have been developed. The authors analyzed 18 designs from engineers in Azerbaijan, Kazakhstan, Russia, and Georgia that utilize recycled tires [3]. These designs can be divided into four groups: 1) mudflow protection structures where recycled tires are used as damping and cushioning elements;

2) structures primarily consisting of recycled tires connected in blocks with flexible cables and fasteners; 3) structures where recycled tires are variously threaded onto stakes driven into the riverbed or anchored to a foundation; 4) complex mudflow protection structures where recycled tires work in conjunction with horizontal and vertical beams, as well as anchored flexible connections, functioning as permeable, deformable structures. Research shows that the simplest and most reliable designs are those in the third group.

In recent decades, engineers have noted the potential for using recycled tires as structural components for bank stabilization retaining walls [4]. Retaining walls made from recycled tires are threaded onto piles and secured to the foundation with tensioned flexible cables. Some designs use both piles and tensioned flexible cables. The cavities of the tires may be empty or filled with soil or dry ballast.

The authors have developed a device to protect riverbanks from erosion. The bank stabilization structure includes piles placed at equal distances. Recycled tires are threaded onto the piles, with adjacent rows laid in staggered patterns. The cross-section of the piles should be elliptical, matching the cross-section of the through hole formed when laying tires with staggered seams in adjacent rows. After driving the piles, the tires are threaded in rows; for example, the first row is threaded onto the piles such that each tire is threaded onto each pair of piles starting from the second pile, and so on, depending on the design. This results in the staggered placement of tires.

Heavy rainfall, intensified by global climate warming, leads to noticeable erosion processes. There are many design innovations for anti-erosion structures made from recycled tires. The authors analyzed 109 patents for inventions from the former USSR, the Russian Federation, and the Republic of Azerbaijan. These structural solutions can be classified into 5 classes [5]. The first class includes structures made from whole recycled tires [6]. The second class consists of anti-erosion structures made from whole and cut recycled tires [7]. The third class includes anti-erosion structures made from recycled tires cut in various ways. The fourth class consists of anti-erosion structures assembled from blocks of recycled tires. The fifth class includes complex anti-erosion structures where recycled tires are used not only as protective coverings but also as anchoring and reinforcing elements; where elements made from recycled tires are combined with reinforced concrete and other structural elements; and where recycled tires are connected horizontally and vertically with metal cables and used as flexible dams placed across water flows.

V. On the Use of Recycled Railway Concrete Sleepers in the Construction of Protective Structures Against Catastrophic Natural Phenomena

Decommissioned railway concrete sleepers accumulate in large quantities and are often sent for disposal. Currently, there are three methods for recycling concrete sleepers:

– storing or burying them at designated sites and landfills;

– using concrete sleepers in the construction of lightweight building foundations;

– processing concrete sleepers in crushing plants to obtain artificial gravel and scrap metal in the form of broken reinforcement.

Using whole recycled concrete sleepers for constructing protective structures is a highly economical and environmentally friendly approach, as it eliminates the need for costly and energy-intensive processing. Their residual strength is sufficient to effectively counteract the negative forces created by catastrophic and emergency natural phenomena and processes. Numerous designs have been developed by engineer Yu.P. Kozhin, et al. Notable examples include structures for avalanche and mudflow protection [8], retaining walls with various configurations utilizing recycled concrete sleepers [9, 10, 11], bank stabilization structures made from interconnected recycled sleepers [12], and modular frames containing protective plates fixed to counterforts [13], which are shaped like triangular frames. Additionally, there is a design for river regulation aimed at protecting riverbanks from erosion [14].

The authors have developed bank stabilization structures that incorporate recycled concrete sleepers into the shelves of channel (or I-beam) piles. Standard metal channel or I-beam profiles are used as piles. Various mudflow protection structures have also been developed, where horizontal beams in the form of recycled concrete sleepers are inserted onto different notched posts anchored to the riverbed.

The unique mechanical and geometric properties of recycled steel-belted tires and concrete sleepers present engineers with opportunities to create new cost-effective protective structures against various catastrophic phenomena caused by global climate change on Earth.

VI. Conclusions

1. Global warming is accompanied by intense snowmelt and evaporation. The cloud cover accumulated in the atmosphere contains a vast amount of water, which falls as prolonged heavy rainfall, resulting in catastrophic floods, mudslides, landslides, and erosion processes.
2. The most common type of consumer waste consists of recycled automobile and tractor tires. The unique geometric and mechanical properties of steel-belted recycled tires allow for their effective use in the design of protective structures. The authors have developed relatively simple and cost-effective protective structures made from recycled steel-belted tires for use during floods.
3. The authors analyzed 18 designs of mudslide protection structures developed by engineers from Azerbaijan, Kazakhstan, Russia, and Georgia that utilize recycled tires.
4. In recent decades, engineers focused on the potential use of recycled tires as structural components in bank stabilization retaining walls. The authors developed a device for protecting banks from erosion. The bank stabilization structure includes piles placed at equal intervals, onto which recycled tires are threaded, with adjacent rows laid in staggered seams.
5. The authors analyzed over a hundred patents for anti-erosion structures made from recycled tires. These design solutions can be divided into five classes.
6. Decommissioned railway concrete sleepers accumulate in large quantities and are often sent for disposal. The use of whole recycled concrete sleepers for constructing protective structures is highly economical and environmentally friendly, as their residual strength is sufficient to effectively counteract the negative forces created by catastrophic and emergency natural phenomena and processes.
7. The authors analyzed known designs for avalanche and mudflow protection, retaining walls with various configurations using recycled concrete sleepers, and bank stabilization structures made from interconnected recycled sleepers and modular frames securely fixed to counterforts. There is also a design for river regulation intended to protect riverbanks from erosion.
8. The authors developed bank stabilization structures that incorporate recycled concrete sleepers into the shelves of channel (or I-beam) piles. Various mudslide protection structures have also been designed, where horizontal beams in the form of recycled concrete sleepers are inserted onto different notched posts anchored to the riverbed.

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