CLIMATE CHANGE AND ITS IMPACT ON BUILT ENVIRONMENT ALONG WITH REMEDIES TO ENSURE SUSTAINABLE AND RESILIENT SOCIETY

Aditya Singh[*1], Amit Srivastava[2]

[1]*Amrita Vishwa Vidyapeetham, India, e-mail: aditya7777777k@gmail.com*
[2] *Graphic Era Deemed to be University, India, e-mail: amitsrivastava.ce@geu.ac.in*

***Corresponding Author**

ABSTRACT

Climate Change is a major issue in the modern world, and it is also the main cause of many of the recent problems which greatly affected the whole world in a negative way. Due to considerable changes in the weather conditions in the recent decades, buildings and many types of structures are also being affected by it. This is further affecting the civil engineering domain and putting pressure on civil engineers to make sure that the ongoing projects or upcoming ones are eco-friendly as well as to reduce the damages on structures due to the climate change. The current study pointed out the problem related to deterioration of structures due to Climate Change particularly in India in the recent years. This paper will help people to not only understand climate change but how it is affecting the buildings as well as various structures. It will discuss the deterioration of the structures causing life of the structures to shorten than designed. The paper will cover some instances from Indian conditions and their aftermath. Further, some possible solutions will be discussed in this paper. Then, graphical analysis will be performed on the available data from various sources, to support the study. Through this study, some feasible solutions to overcome or to minimize the negative impact of the ongoing Climate Change on the structures as well as to extend their life, are provided.

Keywords:*Climate Change, Temperature, Structures, Floods, Sustainable*

1. INTRODUCTION

The term Climate Change is used when there is long term changes in the pattern of weather as well in temperature. This change can be because of natural reasons like if there are large volcanic eruptions in some places in the world, then that can also lead to climate change up to certain extent. The same can be said if there are changes in the orbit of the Earth, which can affect the incoming sunlight from the sun greatly, leading to climate change. Then, contenental drift and even fall of large metorites can affect the Earth drastically, contributing towards climate change. However, human activities also lead to the Climate Change, for instance artificial arosols, greenhouse gasses, as well as the shift in land use pattern, negatively affects the environment of the planet, which further accelerates the Climate Change. From the 19th century onwards, the main leading factor towards Climate Change, has been human activities, mostly because of the burning of fossil fuels such as gas, oil, in addition to coal. Due to burning of fossil fuels, greenhouse gasses are released, which are responsible for ensnaring the heat of the sun, leading to the rise of the temperature of the whole planet. Then, the release of CFCs, halons, in addition to HCFs, from the modern electronic products commonly used in the corporate offices, commercial places and residential places, lead to the depletion of the Ozone layer, which is also a minor factor towards the global warming and Climate Change. However, greenhouse gases mostly which contribute to the Climate Change, are methane in addition to carbon dioxide. Such harmful gases are produced by using nonrenewable sources of energy in transportation system, in the production of electricity and in the heating of buildings. Further, construction activities and defforestation to increase the agricultural lands as well as to promote urbanization, are also heavily leading to Climate Change. The chief sources of the release of methane are operations associated to gas, oil, as well as agriculture. Further, the main sectors which cause the emission of greenhouse gases are buildings, energy, land use, industry, agriculture, in addition to transportation. According to the climate scientists, the activities of people over the past two hundred years not only the major cause of Climate Change, but also accelerated the Climate Change significantly compared to what it was in the last 2 millenniums. Currently, it is said that the average temperature of the surface of the planet Earth is 1.1^0 warmer in comparison to the late 19th century, as well as anytime in the past one hundred thousand years. As per the record, the past decade (which was from the year 2011 to the year 2020) was the warmest so far, in addition to each of the past 4 decades has been warmer in comparison to any decade in the past from the mid 19th century onwards. Most of the people think that climate change only limited to the increase in temperature, neverthless they forget that it is way beyond that, as this planet is a system where everything is linked with the other things, so if the balance is disturbed in one thing then it alters every other thing, which has drastic affect on the whole planet. The results of climate change at present comprises scarcity of water, catastrophic storms, intense droughts, flooding, declining biodiversity, rising sea levels, melting polar ice, severe fires, and so on. Climate Change also affects housing, people's health, work, ability to grow food, as well as safety. People living in developing countries as well as in small island nations, have been already vulnerable to the impact of the Climate Change. For instance, people had to relocate to other places due to the intrusion of saltwater as well as rise of sea level in their native places, where people in communities were originally living in considerable number, in addition to the prolonged droughts are increasing the risk of famine, which will further worsen the situation. It is said that in the future, it is expected that due to weather associated events, more number of humans will be displaced with time. According to the series of reports of the United Nations, thousands of reviewers in addition to the scientists approved that by limiting the rise of the temperature of the surface of Earth to maximum up to 1.5^0 C or less might aid in preventing the nastiest impacts of the Climate Change as well as assist in maintainng a comfortable climate. Nonetheless the present policies which exist indicates that it might rise almost double the permissible limit in the temperature rise of the planet by the end of this century. It is true that the release of greenhouse gases which is a major cause of Climate Change, comes from throughout the whole world as well as affect all the humans, neverthless some countries are way more responsible for it than others. As per the records, the 7 biggest emitters are responsible for almost 50% of the worldwide release of greenhouse gases in the year 2020, which comprises of China, USA, India, EU, Indonesia, Russia, as well as Brazil.

1.1 The Indian Condition

In India, it can observed that the Climate Change has an intense effect on the country, this could also be noticed in the year 2015 list of countries which were utmost affected by Climate Change, where India's ranking was 4th in the world. The country realeases roughly three gigatonnes of greenhouse gases every year, which is roughly 2.5 tons/person in the country that is comparedly lower than the world's average. However, it cannot be denied that the country emits seven percent of the worldwide emissions of the greenhouse gases, which is also a major contribution to the Climate Change. Due to Climate Change, the intensity as well as frequency of heatwaves are expected to rise in the country. Then, intense floods in addition to landslides are forecasted to rise in number in Indian states like Assam. The country is ranked at the 8th position among the sixty three countries that are responsible for ninety two percent of all greenhouse gases releases in 2021, based on the climate change performance index. Further, compared to the beginning of the 20th century, the temperature of the country has risen by 0.7^0 C by the year 2018. It is also forecasted that by the end of the 21st century, the intensity as well as the number of droughts are expected to rise greatly. In comparison to China, India is releasing carbon dioxide way lower than the former, but in the case of the latter, the number is rising way more rapidly. If the release of greenhouse gases is considered, then the country is ranked as the 3rd largest emitter in the world as well as the chief source behind is coal. According to September 2023, India produces 60.2% of the country's electricity from fossil fuels, which coal contributes fifty one percent in it. Then to support coal fired power stations in the country, not only coal mining is done but import of coal is also done, which is also a mjor concern at present. Further, about 25% of emissions of greenhouse gases comes from industries, mostly from the production of cement, steel, in addition to iron. It is said that the consumption of fuel increased by four hundred six percent by the Industrial sector compared to what it was in the beginning of the 21st century and what it reached by the year 2014. Hence, by the year 2014, industries were consuming forty two percent of the energy. Due to the burning of crops as well as utilization of artificial fertilizers, it was observed that between the years 2005 to 2014, there was an increase of twenty five percent in the release of agricultural emissions of greenhouse gases in the country. Further, in the year 2014, seventy eight metric tonnes of carbon dioxide equivalent was released by the waste in the country. Last year in the month of may, i.e. in the year 2022, intense heatwave was observed as per the records in both India as well as in Pakistan. Due to Climate Change, the occurence of intense heatwaves increases by about one hundred times, as in normal case intense heatwave occurs once in every three hundred twelve years, but due to Climate Change, such intense heatwave occurs in every three years. Based on the study in the year 2018, it is expected that there will be increased in droughts in upcoming future in not only in North-western part of India, but also the whole Northern region. Warmer air increases the precipitation, which also changes the intensity and arrival of rainfall, which can also be associated to the recent unexpected floods in the country.

1.2 Objectives

There are many objectives of this study, which are as follows:

- To understand Climate Change in the general sense and its effect in the world.
- To understand the effect of Climate Change in the Indian conditions.
- To understand and find out Civil Engineering solutions to reduce the current problems.
- To perform graphical analysis in regards to the Climate Change to support the study.

2. MOTIVATION

The authors observed that the Climate Change is a major problem accross the world and in the past decades this problem further increased. Then, the ground reality is far away compared to the anticipated desired goal to control or reduce the ongoing accelerated Climate Change. They also noticed that their home country is also included in the list of major emitters of greenhouse gases in the world and they noticed the severe effect of Climate Change in India particularly in the last decade. Also, due to Climate Change, it was observed that the intensity as well as number of heatwaves increased in India in the recent years, similarly, warmer temperature also lead to increase in rainfall. Furthermore, the frequency and intensity as well as arrival of rainfall greatly changed in the past years, also unexepected floods,

increasing droughts, and other problems led to the increase in deaths, damage of property, structural as well as infrastructural damages, along with monetary losses. This led the authors to procceed with their study on Climate Change and on finding out possible civil engineering solutions to decrease the current problems due to Climate Change, up to certain extent.

3. LITERATURE REVIEW

Guo et al. (2023) studied climate change and they worked on not only on permafrost change but also its engineering effects under their studied area. Further, they also considered the scenarios associated to the construction of airport in the case of northeast China, to accomplish their studies. Chen et al. (2023) studied main climatic factors and they examined them in regards to the way they affects the roughness of asphalt pavement in various regions with dissimilar climate. Wojkowski et al. (2023) studied climate change as well as reason behind the loss of the capacity of the storage of water, by choosing catchment areas particularly in the East Central Europe region, to analyse the hydric potential of the landscape in their chosen areas. Gobert (2023) studied not only rivers but also climate change, as well as how infrastructure could change the situation. Thasneem et al. (2023) worked on unsurety in the case of forecast of the flow of monsoon in the future in regards to the forecasted climate change, by considering the case of Chaliyar River Basin, through their study. D'Ambrosio et al. (2023) worked on Sustainable Drainage Systems which served as ther adaptation plan for climate change, and they also performed an analysis which was on the basis of a scenario, intended for an urbanized catchment area especially in the region of northern Italy, to obtain desired study outcomes. Shakeri et al. (2021) studied climate change and they worked on predicting its impact on the alterations in the generation of municipal wastewater, which was intended for projects like wastewater reuse ones. Mishra and Sadhu (2023) studied climate change and they worked on finding out how it affects the structural loads in the case of urbanized infrastructure through their study. Li et al. (2023) studied the climate change mitigation plans and they worked performed an analysis which was on an actual choice based decision making model, to be used in the case of buildings. Liu et al. (2023) studied climate resilience infrastructure and they worked on not only hotspot but also knowledge map analysis in the direction of their studied area, from the year 1997 till the year 2022, with the assistance of scientometric analysis. Shao et al. (2021) considered New York's Adirondack region for their study and they futher saw the response of the streams present in it, in order to forecast the alterations in not only nitrogen but also sulfur deposition under the influence of climate change. Cho et al. (2023) studied the governance of national climate change of the country South Korea, and they accomplished their studies by perceiving the case of government committees of both liberal as well as conservative ones in their country in regards to their studied area. Moghadam et al. (2023) studied climate change and they examined the performance of models which were based on lumped, data mining, as well as distributed ones in the case of runoff forecasted under it. Watari et al. (2023) studied climate crises and they worked on the concrete's increasing role in sand as well as in regards to their studied area, to obtain the desired results. Ho et al. (2023) studied climate change and they worked on alteration in flood in relation to the rainfall losses under it, to accomplish their studies.

4. METHODOLOGY AND SOLUTIONS TO MEET CLIMATE CHANGE ISSUES

- Sustainable Transportation
- Climate Resilience Infrastructures
- Green and Sustainable Construction
- Smart Construction materials and Techniques

4.1 Sustainable Transportation

According to U.S. Department of Energy *"Sustainable transportation refers to low- and zero-emission, energy effecient, and affordable modes of transport, including electric and alternative-fuel vehicles, as well as domestic fuels."* The benifits includes cost savings, low carbon emission, improved acessibility, improving employability and better energy security. Extensive research for clean energy technologies

will be required to meet the demand of changed perspective, designing transportation infrastructure to make it effecient, safe, reliable and affordable based on ″energy effecient mobility system″ concepts. Additional funding is required for creating extensive battery charging points, designing community movement plan, roads and bridges to meet the requirements of sustainable transportation infrastructure. To meet the target ″Net Zero by 2070″ as per 26th session of United Nations Framework on Climate Change, Nov. 2021, decorbonization of transportation sector will be a major challenge and a blueprint is to be created in cooperation and coordination with other sectors in PPP model involving others from energy, transportation, urban planning and development, Housing, Environement etc.

More focus should be on sustainable vehicles, i.e., low or No carbon emitting vehicles, Hybrid Vehicles, Electric Vehicles, along with improving public transportation system. Additionally, extensive research is required to develop sustainable fuels, such as, Ethanol, Hydrogen, Natural Gas, Propane, Biodiesel, that help reducing carbon emissions. Advanced batteries should be researched to improve driving lengh and reducing charging time and frequency. Disposal of batteries will again be a major environmental issues that need to be researched. Dream of sustainable Transportation can only be fullfilled through law enforcement and incentives for using alternative fuels and energy effecient and sustainable vehicles.

4.2 Climate Resilient Infrastructures

In recent times, extreme events like heavy rainfall, floods, wildfires, Cyclones, Droughts, Heat waves due to climate change causing huge damage to infrastructure, loss to life and unrest in the society. With reference to Fig. 1, examples of Heavy Rainfall, floods and landslides in the year 2022 in India claimed 3026 human lives, affected 1.96 million hectares crop area, destroyed 423,429 houses and killed 69,899 animals.

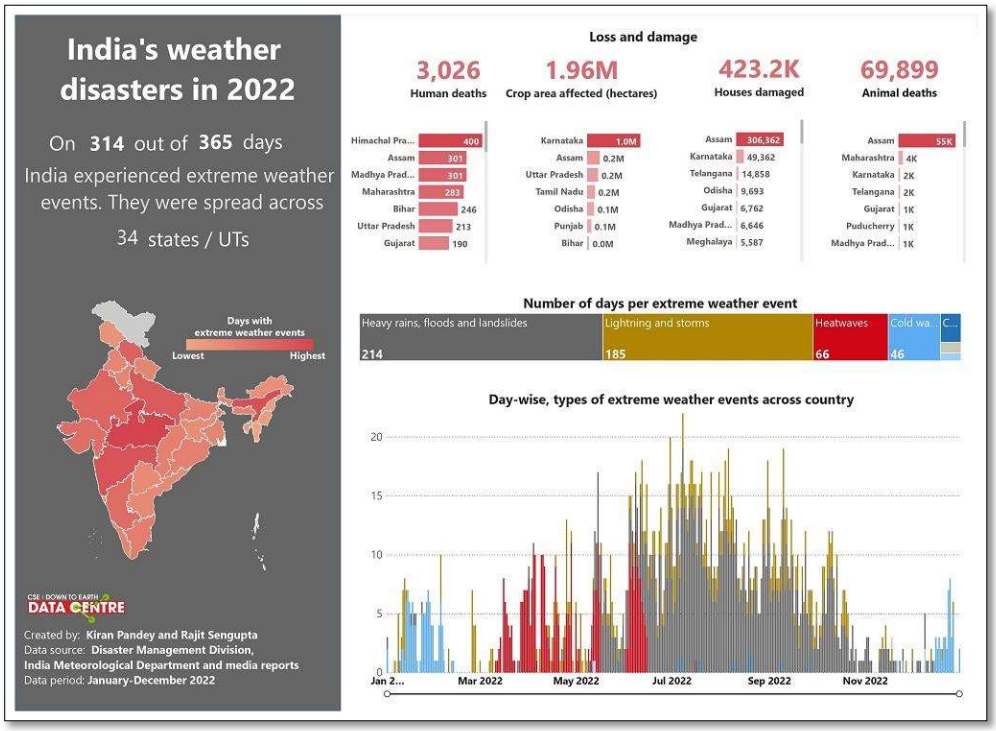

Figure 1 India's weather disaster in the year 2022 (Source: India Metrological Department and Media Reports, https://cdn.downtoearth.org.in/library/large/2023-01-17/0.52133400_1673949342_extreme-weather-events-india-2022---factsheet_page-0001.jpg

AS per OECD (https://www.oecd.org/) Environment Policy Paper No. 14, "*Climate resilient infrastructure are planned, designed, built and operated in a way that anticipates, prepares for, and*

adapts to changing climate conditions. It can also withstand, respond to, and recover rapidly from disruptions caused by these climate conditions". The extent to which climate change translates into risks for infrastructure depends upon the interaction of changing climate hazards with exposure (the location of assets) and vulnerability ("the propensity or predisposition to be adversely affected") (Agard & Schipper, 2014).
There is an urgent need to pay attention on the issues before it's too late to respond. New infrastructure should be planned, designed, built and operated to meet the new challenges of extreme events due to climate change. Existing infrastructure should be retrofitted or should be managed in a way to meet the requirements.

Climate resilient Infrastructure adaptation measures are grouped into (i) structural and (ii) non – structural measures ((EUFIWACC, 2016). Examples of Structural measures are such as building road surfaces that does not deform in high temperature, constructing sea walls, provision of permeable surface that reduce runoff Non-structural measures could be related to management of assets and their locations, its maintenance (changing frequency and timings), investment on early warning system for better monitoring, financial set up for insurance. Few concerns for better planning and designing of climate resilient infrastructure with need for extensive research and development activities are indicated as below:

- **Temperature rise** cause melting of road surface, buckling of railway lines, alternate freezing and thawing case damage to the road infrastructure, there will be reduced output from the energy sectors, such as, thermal power plant, solar panels, reduced heating and increased cooling demand from urban sectors, increased evaporations from reservoirs, increased demand for water treatment, cooling demand for data centres etc.
- **Rise in sea level** may lead to inundation of transport infrastructure in the coastal region, including sea ports that will also affect the energy sector involved as generation, transportation and distribution systems, submergence of urban area in the coastal region, relocation strategies for native people, salinization of ground water etc.
- **Changing pattern of precipitation** will after transportation through inland waterways, reduced output from hydropower plant, increased risk of flooding and subsidence to urban infrastructure, water storage demand, overtopping of dams etc.
- **Changing storm pattern** cause damage to infrastructure, specially bridges, ports and airports, in energy sectors it may lead to damage to distribution networks, damages to wind farms, damage to residential buildings and loss of life, and damages to hydro projects and so on.

Structural adaptation measures will require construction of sea walls for the protection of coastal area, cooling towers and additional facilities for improving cooling capacity, new infrastructure in low risk area, increasing the height of transmission line towers, Bridges, or going underground to protect from flooding, using smart, sustainable and green materials for buildings and infrastructure projects, ensuring energy efficient buildings, new design criteria and so on.

Non-structural measures or management adaptation measures include revised maintenance schedule, close coordination with metrological department to review the risk associated with existing infrastructure under climate change and extreme events, disaster risk reduction plan, quick emergency response, training local residents, improving upon awareness program and public education and so on as per the local need.

4.3 Green and Sustainable construction

As per the Global Development Research Centre (GDRC) (https://www.gdrc.org/), "*Architecture, construction and the environment are inextricably linked - energy, materials, water and land are all impacted and/or consumed in the design, development, construction and operation of buildings*." Energy Efficiency, Water Conservation, Sustainable materials, Indoor air quality, Waste reduction and recycling, site and land use are main key features of the green construction. Sustainability is part of achieving green construction.

Energy efficient buildings should be designed and operated in such a way that it utilizes the minimum energy required to maintain the need of the energy for lighting, good air, insulation, that minimize the use of HVAC (Heating, Ventilation and Air Conditioning) system and dependent on natural resources including solar panels and solar power / energy.

Water Conservation is ensured through rain water harvesting system, fixtures that reduce the waste water through managing the outlets, recycling the grey water and minimizing the water consumption for irrigation and gardening.

Sustainable materials means materials that are recycled and reused, waste materials used in the construction, maximum utilization of local materials and resources to reduce transportation cost and also using materials that are environmental friendly, such as green materials, Bamboo in construction, earth materials.

Indoor air quality is ensured through proper building design and operation, use of natural sources for light, proper ventilation, indoor planting, using non-toxic and non-emitting materials for interior designing. This ensures improvement in the occupant productivity and reducing the risk associated with health.

Waste reduction and recycling requires waste characterization and integrated waste management system to ensure fulfilment of waste to energy concept. Major focus should be on construction and demolition waste. It should be ensured that minimum should go to landfill and "zero waste society" concept should be implemented at all level of planning, designing and execution of waste management.

Site and land use put emphasis on minimum disruption to the site while designing and execution of the construction work, natural features should be preserved and this can be achieved through proper site selection, orientation and landscaping for ensuring energy efficiency and sustainability.

4.4 Smart Construction Materials and Technologies

Smart Materials also called as Intelligent Materials, or Adaptive Materials are those materials that respond to the environmental changes, such as, temperature, Light, Moisture, pH value, magnetic or electric field, mechanical forces or strains. Classifications are based on input or the output response to the external environmental inputs, such as Shape Memory Alloys (SMAs), Piezoelectric Materials, Magnetostrictive Materials, Electrochromic Materials, and Electrorheological fluids. Few promising materials that have been incorporated in the construction technology with their benefits are summarized in a tabular form (Table 1).

Table 1 Types of Smart Materials used in the construction industry and their benefits

Sr. No	Name of the Material	Potential Application
1	Smart Concrete (concrete mixed with carbon fibres)	Sensing micro cracks or flaws; Electromagnetic Shielding, Improving the electrical conductivity of concrete; melting ice during snowfall; traffic sensing recorder
2	Smart Materials for smart buildings	Vibration Control, Noise Mitigation, Improving Safety and Performance of structure; Indoor environment control, Structural health monitoring, Improving the safety and comfort
3	Smart Materials for Rail and Marine Transport	Strain Monitoring through embedded Fibre optic sensors for better integrity and identifying the trouble area

4	Smart Materials for Bridges application	Reducing vibrations due to wind, rain or traffic thereby requiring less maintenance and provide better monitoring for durability
5	Light Transmitting Concrete with optical fibres	To transmit light and improve the interiors with improved comfort
6	Pervious Concrete	With little or No fines, the concrete become highly porous and allow the water to pass through. It has potential application to provide paved porous surface that allow the rain water to infiltrate into the ground thereby reducing the amount of surface runoff and subsequent flooding
7	Aerated Concrete or Foamed Concrete (with aluminium powder mixed in cement, lime, water and fine grounded sand)	Autoclave Aerated Concrete (ACC) blocks are produced worldwide having density approximately $1/5^{th}$ of the conventional concrete and widely used in construction industry as interior walls, partition walls and curtain walls
8	Floating Concrete (by replacing sand and aggregate with tiny polymeric spheres)	Stronger and lighter concrete that can float on water and such concrete has potential to be used in offshore construction projects

Smart Technologies in Construction is revolutionizing the sector through automation and data driven construction. Artificial Intelligence & Machine Learning, Drone Technology, Sensors, and platforms like Building Information Modelling are providing real time data and invaluable information for better decision making, saving time and reducing project cost. ML algorithm ensures automated control based on the data and environment captured, quick identification of real time problem faced during the construction and helps in optimizing the resources and time. In the same way, AR/VR (Augmented Reality / Virtual Reality) helping smart construction for site virtualization, design review and safety training. It should be noted that in time to come “technology will not replace people but will be replaced by those who use the technology”. Fig. 2 provides a summary of some of the smart technologies and trends observed in the construction industry.

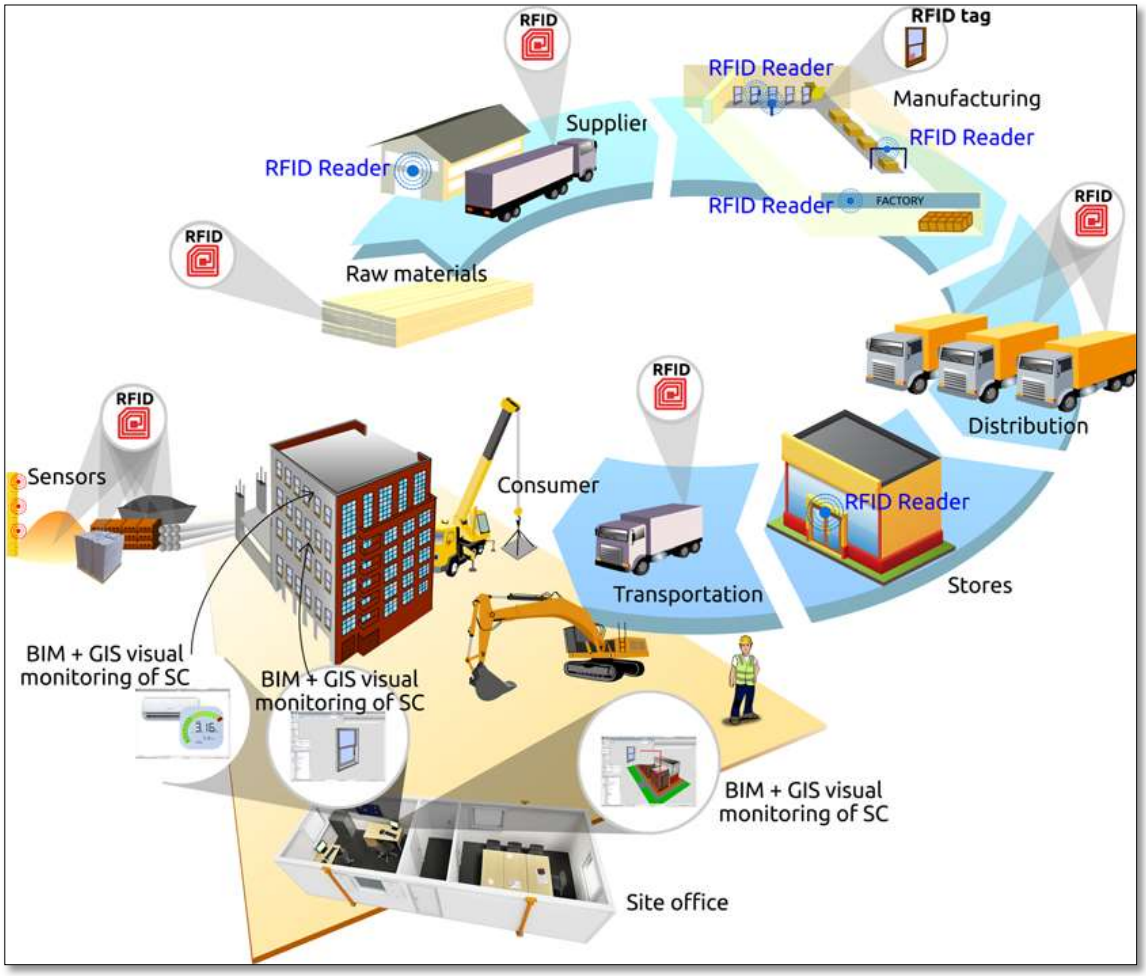

Figure 2 Smart Technologies for Smart Construction (adapted from Ruwini Edirisinghe 2019, DOI 10.1108/ECAM-04-2017-0066)

5. RESULTS AND DISCUSSION

In this section, data from various sources was collected to perform graphical analyses, which are as follows:

5.1 Trends and Challenges of Climate Change

In this subsection, based on the above graphs, the trends as well as challenges are identified, which are as follows:

- According to Fig. 3, Land Use Emissions towards greenhouse gases, was over five thousand tonnes in 1941, but by the year 2017, it was over three thousand seven hundred tonnes. It is safe to say that in 76 years, the emission of greenhouse gases due to land use decreased by over one thousand six hundred tonnes or about 30% reduction was achieved. This also shows that the Land Use policies were improved over the decades to get a positive result.
- According to Fig. 4, the emissions of greenhouse gases by Fossil Fuels and Industry was close to five thousand tonnes in the year 1941, but by the year 2017, it reached over thirty six thousand tonnes, which means that in the span of 76 years it increased by over 7.3 times. This also shows the heavy reliance on Fossil Fuels and Industry over the decades for the development, which means that there is a need to find a suitable alternative for future future development which can be sustainable and ecofriendly.

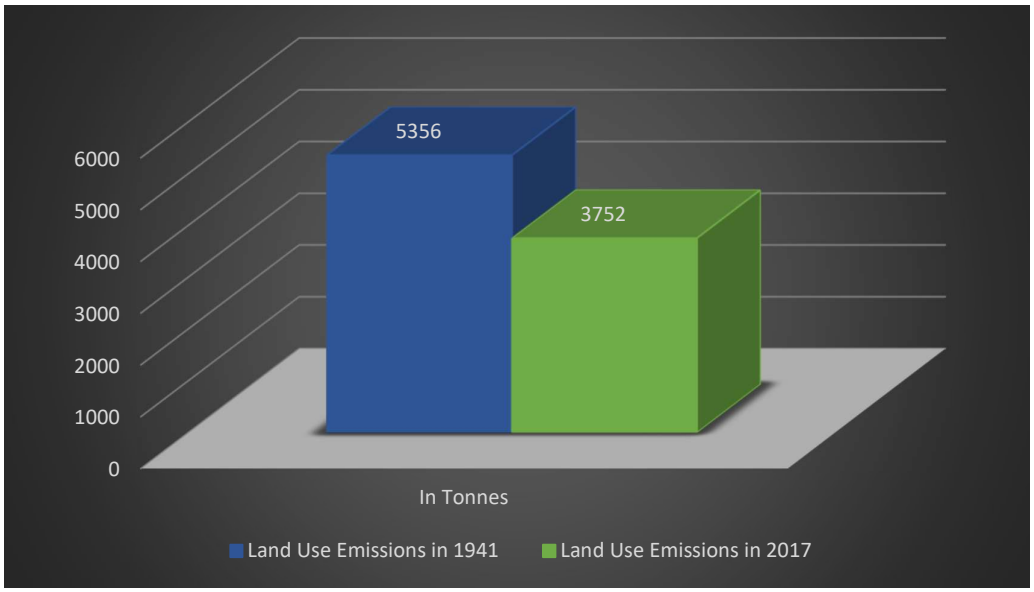

Figure 3: Land Use Emissions (Source: Our Better World)

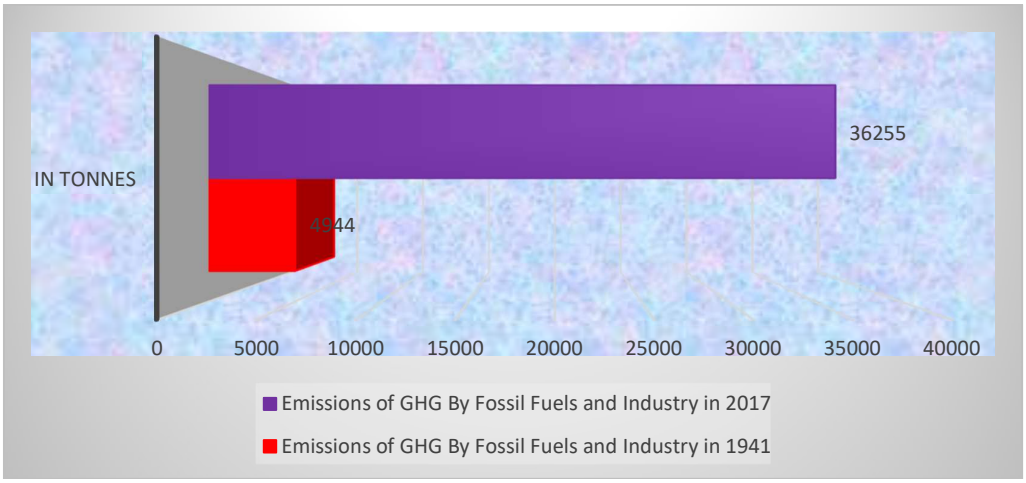

Figure 4: Emissions of GHG By Fossil Fuels and Industry (Source: Our Better World)

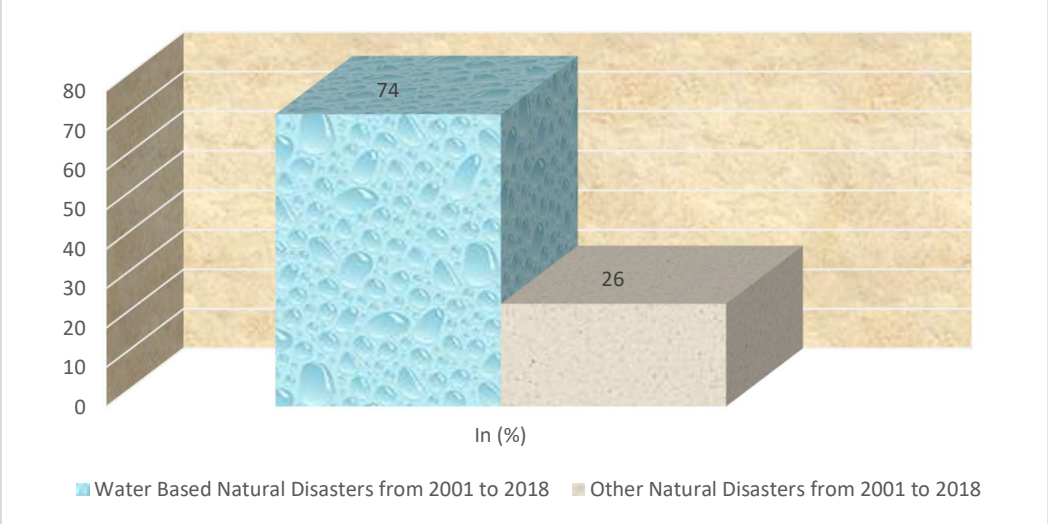

Figure 5: Natural Disasters (Source: UNICEF)

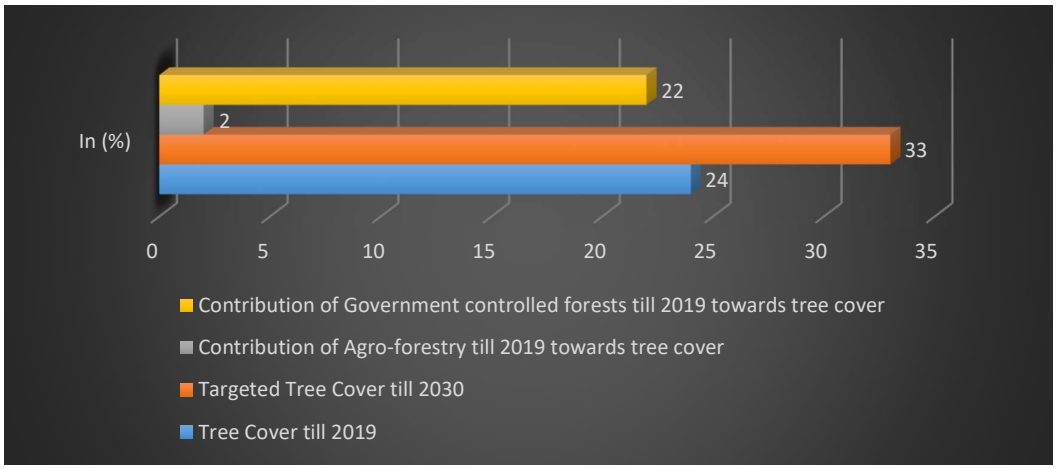

Figure 6: Afforestation In India (Source: Earthworm)

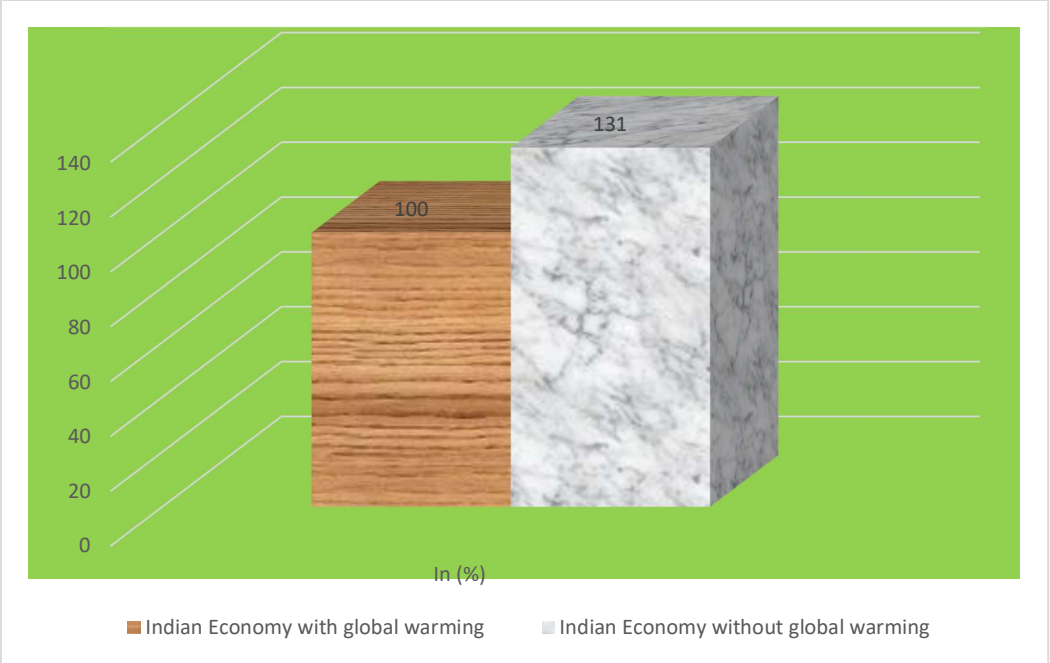

Figure 7: Global Warming's Impact on Indian Economy (Source: Earthworm)

- Based on Fig. 5, from 2001 to 2018, about 74% of the natural disasters were water based ones, which included floods as well as droughts. Due to Climate Change, there has been irregularity in rainfall, the intensity as well as arrival of rainfall has also been changed considerably. This has also led to frequent occurences of floods and droughts. It is safe to say that there is a need of sustainable suitable infrastructure to deal with such problems, which are expected to rise in the future.
- According to Fig. 6, India's move towards green cover or afforestation has been showing positive results. However, it is mostly because of the government controlled forests. It is also essential that NGOs, corporates and individuals also contribute further to help the country in the long run.
- Based on Fig. 7, the Indian economy has been reduced significantly due to the increasing presence of global warming, which means that for economic development of India, it is also necessary to solve the problem of Climate Change.

6. CONCLUSIONS

- Present trends and challenges due to climate change and its impact on existing infrastructure are discussed. Addtionally, structural and nonstructural measures are suggested to mitigate the impact of extreme events and ensuring the climate reslient infrastructure development.
- Data indicates serious issue of carbon emission and achiving ″net Zero″ by 2070 means requirement of extensive research, funding, involvement of all stakeholders through PPP models, laws and their enforcement as well as incentives.
- Use of Smart Materials and Smart Technologies can be of great help provided future generation is equipped to use such technologies. Civil Engineering curriculum at the UG and PG level should be redesigned to cater the need of future. New courses should be introduced. Extensive training is required to create smart work force.

REFERENCES

Agard, J. and L. Schipper (2014). "Glossary", in IPCC Fifth Assessment Report, https://www.ipcc.ch/pdf/assessment_report/ar5/wg2/WGIIAR5-AnnexII_FINAL.pdf (accessed on 14 November 2023).

Chen, C., Deng, Y., Li, M., and Shi, X. (2023)."Investigation of key climatic factors affecting asphalt pavement roughness in different climate regions." *Transportation Research Part D: Transport and Environment*, Volume 122, 103877.

Cho, B-K., Chung, J-B., and Song, C-K. (2023). "National climate change governance and lock-in: Insights from Korea's conservative and liberal governments' committees." *Energy Strategy Reviews*, Volume 50, 101238.

D'Ambrosio, R., Longobardi, A., and Schmalz, B. (2023). "SuDS as a climate change adaptation strategy: Scenario-based analysis for an urban catchment in northern Italy." *Urban Climate*, Volume 51, 101596.

Deutsche Welle, https://www.dw.com/en/climate-change-in-india-a-growing-environmental-crisis/a-66190451#:~:text=The%20rains%20also%20often%20cause,and%20ferocity%20of%20the%20floods.

Earthworm, https://www.earthworm.org/news-stories/change-the-climate-india?gclid=Cj0KCQiAjMKqBhCgARIsAPDgWlxaAUwZdA05LKDFv9OISVGJgBF5_FqP_-bZbNmD1wYwTZLllepFjf4aApqoEALw_wcB.

Edirisinghe, R. (2019). ″Digital skin of the construction site: Smart sensor technologies towards the future smart construction site.″ *Engineering, Construction and Architectural Management*, Volumne 26(2), 184-223.

EUFIWACC (2016). "Integrating Climate Change Information and Adaptation in Project Development", www.eib.org/attachments/press/integrating-climate-change-adaptation-in-project-development.pdf (accessed on 14 November 2023).

Gao, M., Lu, Y., Yu, W., Xu, L., Hu, D., and Chen, L. (2023). " Permafrost change and its engineering effects under climate change and airport construction scenarios in northeast China." *Transportation Geotechnics, Volume 43*, 101117.

Gobert, J. (2023). "Climate change and rivers: The promise offered by infrastructure." *Total Environment Research Themes*, Volume 8, 100077.

Ho, M., Wasko, C., O'Shea, D., Nathan, R., Vogel, E., and Sharma, A. (2023). " Changes in flood-associated rainfall losses under climate change." *Journal of Hydrology*, Volume 625, Part A, 129950.

India Today, https://www.indiatoday.in/environment/story/india-faces-imminent-challenge-from-climate-change-urgent-action-needed-2431680-2023-09-06.

Li, W., Gong, G., Jia, H., Ren, Z., and Chong, A. (2023). " A real options-based decision-making model analysis for climate change mitigation strategies on buildings." *Journal of Cleaner Production*, Volume 429, 139524.

Liu, Y., Li, Q., Li, W., Jia, L., and Pei, X. (2023). "Knowledge map and hotspot analysis in climate resilience infrastructure (CRI) from 1997 to 2022 through scientometric analysis." *Environmental Research*, Volume 228, 115874.

Mishra, V., and Sadhu, A. (2023). "Towards the effect of climate change in structural loads of urban infrastructure: A review." *Sustainable Cities and Society*, Volume 89, 104352.

Moghadam, S.H., Ashofteh, P-S., and Loaiciga, H.A. (2023). "Investigating the performance of data mining, lumped, and distributed models in runoff projected under climate change." *Journal of Hydrology*, Volume 617, Part B, 128992.

Our Better World, https://www.ourbetterworld.org/series/environment/blog/climate-change-and-lord-rings?gclid=Cj0KCQiAjMKqBhCgARIsAPDgWlwNhgK5IhRBcJGJcI8IXEMxk8qPdOqhvEqG-uMqaDPh3hsnM2vGyoUaAl9XEALw_wcB.

Shakeri, H., Motiee, H., and McBean, E. (2021). " Forecasting impacts of climate change on changes of municipal wastewater production in wastewater reuse projects." *Journal of Cleaner Production*, Volume 329, 129790.

Shao, S., Burns, D.A., Shen, H., Chen, Y., Russell, A.G., and Driscoll, C.T. (2021). "The response of streams in the Adirondack region of New York to projected changes in sulfur and nitrogen deposition under changing climate." *Science of The Total Environment*, Volume 800, 149626.

Singh, A. (2023). "8 Augmented Reality and its use in the field of civil engineering." In S. Badotra, S. Tanwar, A. Rana, N. Sindhwani & R. Kannan (Ed.), *Handbook of Augmented and Virtual Reality* (pp. 117-136). Berlin, Boston: De Gruyter. https://doi.org/10.1515/9783110785234-008.

Singh, A. (2023). "Mechatronics Engineering in the Modern World and Its Use in the Construction Industry." In M. Mellal (Ed.), *Trends, Paradigms, and Advances in Mechatronics Engineering* (pp. 64-92). IGI Global. https://doi.org/10.4018/978-1-6684-5887-7.ch004.

Singh, A. (2023). "The Current Scenario of Sustainable Planning and Development of the Indian Built Environment." In N. Cobîrzan, R. Muntean, & R. Felseghi (Eds.), *Circular Economy Implementation for Sustainability in the Built Environment* (pp. 106-138). IGI Global. https://doi.org/10.4018/978-1-6684-8238-4.ch005.

Singh, A. (2023). "The Present and Future Role of Artificial Intelligence in the Promotion of Sustainable Practices in the Construction Sector." In: Kahraman, C., Sari, I.U., Oztaysi, B., Cebi, S., Cevik Onar, S., Tolga, A.Ç. (eds) Intelligent and Fuzzy Systems. INFUS 2023. Lecture Notes in Networks and Systems, vol 759. Springer, Cham. https://doi.org/10.1007/978-3-031-39777-6_2.

Thasneem, S.A., Thampi, S.G., and Chithra, N.R. (2023). "Uncertainties in future monsoon flow predictions in the context of projected climate change: A study of the Chaliyar River Basin." *Environmental Research*, Volume 222, 115301.

UNICEF, https://www.unicef.org/stories/water-and-climate-change-10-things-you-should-know?gclid=Cj0KCQiAjMKqBhCgARIsAPDgWlzS55er2_CsOczrR-Lft76iGpB-L2VEQf98cuP5v6UZ9qj9ppYB_ssaAlvtEALw_wcB.

United Nations, https://www.un.org/en/climatechange/what-is-climate-change.

Watari, T., Cao, Z., Serrenho, A.C., and Cullen, J. (2023). "Growing role of concrete in sand and climate crises." *iScience*, Volume 26, Issue 5, 106782.

Wikipedia, https://en.wikipedia.org/wiki/Climate_change_in_India#:~:text=India%20has%20the%20world%27s%20highest,2040%20due%20to%20climate%20change.

Wikipedia, https://en.wikipedia.org/wiki/Climate_change_mitigation.

Wojkowski, J., Walega, A., Mlynski, D., Radecki-Pawlik, A., Lepeska, T., Piniewski, M., and Kunzewicz, Z.W. (2023). "Are we losing water storage capacity mostly due to climate change – Analysis of the landscape hydric potential in selected catchments in East-Central Europe." *Ecological Indicators*, Volume 154, 110913.

World Bank, https://www.worldbank.org/en/news/feature/2023/08/17/india-managing-the-complex-problem-of-floods-and-droughts#:~:text=Worryingly%2C%20India%27s%20drought%2Dprone%20area,reaching%20impacts%2C%20affecting%20several%20generations.