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Aim & Scope

International Journal of Advances in Mechanical and Civil Engineering(IJAMCE) is a scholarly online, open access, peer-reviewed, interdisciplinary and fully refereed journal focusing on theories, methods and applications in Mechanical Engineering and Civil Engineering . It is an international scientific journal that aims to contribute to the constant scientific research and training, so as to promote research in the field of Mechanical and Civil Engineering.

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Contents

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Sustainable Approach for Building Materials and Airflow Analysis for Elevated Metro Rail Station Box of Ahmedabad

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ABSTRACT

• ***Purpose -*** *Building Information Modelling has been effectively utilized for energy modelling and analysis widely in the design phase for the complex infrastructure projects. The purpose of this study is to identify and analyse the embodied and operational energy demand of the elevated metro rail station with respect to alternate designs and building materials.*

•***Design/methodology/approach -*** *The total amount of energy consumption of the elevated metro-rail station in Ahmedabad, India, and its annualwind analysis. Evaluation of the alternative building materials and designs to obtain the best in class energy requirements by using Autodesk Revit Architecture 2018 and Green Building Studio.*

• ***Findings -*** *The findings suggest a different set of building materials and sustainable designs leading towards the reduction in the embodied and operational energy consumption through its whole annual life cycle.*

•***Originality/value -****This work enlightens the significant energy savings in terms of embodied and operational energy by using BIM as a sustainable approach for the elevated metro rail station. At last, recommending few alternate building materials and sustainable designs resulting in the reduction of energy usage up to a greater extent for energy-efficient metro rail station leading to a sustainable future.*

Keywords - Building Information Modelling (BIM), Energy Simulation, Energy Efficient metro rail station, Sustainability

I. INTRODUCTION

Climate-change and depletion of non-renewable resources are major issues in the world. The construction and building segment have a significant impact on the global environment because of its massive energy consumption (Shoubi 2015).Based on the study carried out by (Bapat and Sarkar 2019) shows that there are around 549 active metro lines consisting of 11,300 km of infrastructure and 9,200 metro-stations. It also highlights the utilization of fossil fuels to produce more than 80 percent of current energy demand. Even after huge investments in developing renewable and sustainable energy capacities, the amount of world energy consumption has been hardly decreased. It has also stated that buildings contribute almost 40 percent of the total world energy consumption.

Building Information Modelling (BIM) is used as an emerging tool used to facilitate energy-efficient designs of the buildings by 3D modelling and information management throughout the project life cycle (Lu,Wu, Chang, & Li, 2017). Multi-disciplinary information can be incorporated into the 3D model and can also be managed according to the user requirements. Recently, innovative development of BIM has provided opportunities to support an energy- efficient practice, which is known as Green BIM. Green BIM is defined as a model-based process of generating and managing coordinated and consistent building data that facilitates the accomplishment of established sustainability goals (Wong & Zhou,2015).

It facilitates multiple evaluations and performance analysis like carbon emissions, construction management, daylight analysis, operational and embodied energy usage.

The thermal aspect is the main point of investigation for the operational energy of the building as it involves a significant amount of operational energy consumption of the building. Every building consist chain of components with respect to their thermal dissipation. Building design and surrounding environmental conditions are responsible for changes in the rate of energy dissipation. A significant amount of energy savings can be achieved by modifying building materials in terms of heat exchange. Utilization of better alternate building material with better thermal insulation characteristics leads to the minimization of heating and cooling loads resulting into the better economy and reducing greenhouse gas emissions by optimum energy consumption.

Energy-efficient building must include the process to minimize the energy consumption in terms of operational energy which is the energy required during the operation phase of the building used for operations like heating, cooling, power supply to the fixtures and embodied energy which is used in extracting, manufacturing, logistical and installation process. To increase the energy-efficiency, high efficiency building elements like insulation walls, ceiling, and floors should be used, leading to operating energy optimization(Schueter A, Thessling F. 2008).A similar problem is about the implementation of the conventional planning process into which performance and energy analysis are to be carried out after the design of the project and documents have been submitted.

Decisions made in the design phase before construction for a sustainable approach in the design of the project are very significant because of the decision made in the execution phase or maintenance phase, i.e., during or after construction, results in inefficient and costly rework modification process for changing design and construction to obtain the specific performance and energy goals. The information of building orientation, façade, building materials, systems, is essential for assessment of energy performance analysis of the project in the design phase.

This study aims to spot various sustainable design alternatives for energy saving in terms of operational and embodied energy by utilizing BIM and also with the help better alternative materials which have a huge impact on the building performance ensuing reduction in the embodied and operational energy for best in class design of energy-efficient metro rail station.

II. LITERATURE REVIEW

Building Information Modelling (BIM) is an emerging technological and procedural shift within the architecture, engineering, and construction (AEC)(Bashar, 2018)(Theophilus, 2019)(Yaser, 2019). BIMrequired for increased sustainability and productivity on construction sites(Joblot, 2017)(Azhar, 2009). Previously,many different energy modelling techniques have been applied to numerous studies in an attempt to predict future energy usage, including statistical analysis of building consumption data(Tiberiu, 2008)(Betul, 2009)(Shem, 2008)(Thomas, 2009)(Yiqun, 2008).Many researchers are focused on energy- efficiency in building(Richard, 2005)(Nii, 2014). A study by(Yewande, 2019) revealed that the biggest barrier to implementation of energy efficient practices was cost implications. (Zaid, 2014) Has also stated that the construction has focused on the operational and embodied energy of buildings because of more suitability and flexibility.(Pezeshki, 2019)Reviews the Building Energy Modelling (BEM) development using different methodologies based on BIM data. The author reviews with seven types of direction to examine BEM are building energy prediction & estimation, building energy consumption, building energy optimal design, building energy evaluation, building energy efficiency, building energy management, building energy optimization.(Westfall, 2003) Developed different methodology to calculated energy consumption. Some of them are based on statistics and others are based on simulation.

(Hernandez, 2008) In general it's consider to forecastthe energy consumption of building.

For energy consumption (Lisa, 2015) observed that a large percentage of building energy mislaying occurs due to leakage in building envelope, the performance efficiency of the building envelope and equipment of the Heating, Ventilation, and Air-Conditioning (HVAC) systems can reduce a considerable amount of energy consumption of buildings. (Sartori, 2007)Study 60 papers to identify the importance of embodied and operational energy.

(Cheng, 2018)Proposes a methodology to integrate embodied energy and to analyse the embodied energy in constituted of energy intensity of materials, energy consumed during transportation and construction.(Khasreen, 2009)Discussed the methodology of life cycle analysis and reviewed some applications from the perspectives of building and components.(Ramesh, 2010) Concluded that building life cycle energy can be significantly reduced by minimising its operational energy through the use of active and passive technologies. Most of above mention studies were reviewed by (Yung, 2013) who concluded that different authors used different methodologies of life cycle analysis in building due to lack of data and also revealed that most of the embodied energy calculation is based on gross floor area rather than volume of building component.

The methodology of Life Cycle Analysis (LCA) is adopted to obtain the embodied energy. Process Analysis, input-output (I/O) and hybrid analysis are the three approaches used in LCA(Mengyao, 2013). The third approach, which is a hybrid of the above mentioned two approaches, was adopted by the Inventory of Carbon and Energy (ICE) database(Manish, 2006).This database lists different coefficients to represent the impact of a certain material in terms of embodied energy and carbon emissions.(Treloar, 1999)One paper also discussed different materials embodied energy analysis of fixtures, fittings, furniture and they suggested to replace some flexible material with them.In the building energy analysis (Huaquan, 2019) present an algorithm to automatically facet curved walls and convert their geometrics into polyhedrons which can further be processed by existing transformation approaches. Industry Foundation Classes IFC BIM- to-BEM transformation approaches are not fully capable of handling building object with a curved surface in IFC modelling.

(Zhang, 2016) Believe that to discover the main source of input parameters, the great impact on building energy efficiency is one of the main challenges of building performance analysis. Critical input parameters can be determined by the use of sensitivity analysis models. (Sergio, 2018) Information exchange between building information modelling (BIM) and Building Energy Performance Simulation (BEPS) tools using the InformationDelivery Manual (IDM) and Model View Definition (MVD) methodologies. MVD development focused on geometry data with a little specification of

HVAC components and properties.(José, 2019) BIM has great potential for optimizing sustainable building even though it is not so oriented to sustainable building and it also analyse show using BIM can contribute to optimizing BSA methods. Both BIM software and plug-ins still need improvements and further developments in this field in order to be suitable to use for BSA purposes. With the development of SB Tool BIM, major contributions are expected to improve the sustainability level of the building.BIM in green building enables sustainable designs, allowing architects and engineers to integrate and analyse building performance so (Poorang, 2019) investigates if and how IPD can assist BIM implementation and also identified the main barriers to implementing IPD, which if overcome, could improve construction performance in terms of cost, time, efficiency and productivity.(Dat, 2019)So encourage green star development with more extensive education playing a critical role, combined with greater interaction of BIM with green star.(Mark, 2019) the proposed taxonomy is 1) for the project phases the design, construction, operation and renovation processes of green building; 2) for the green attributes analysis such as energy, emission, solar & lighting and ventilation analysis; 3) the application of BIM in supporting Green Building Assessments (GBA).So some papers provides future research based on delivering lean and green project outcomes using BIM (Ahuja, 2018). (Zhou, 2019)(Edirisinghe, 2015)(Chong, 2017)(Qing-Hua, 2012)(Smith, 2014)(Ozorhon, 2016)There are six undefined barriers to implement BIM strategies identified from the mapping results such as insufficient government lead/direction, organizational issues, legal issues, high cost of application, resistance to change of thinking mode and insufficient external motivation. For promoting BIM implementation, this study can be used to make the development of appropriate strategies easier within the public and private sectors. (Hong, 2019) The purpose of this paper is to present a model for building information modelling (BIM) implementation at small and medium-sized construction contractor organisations (SMOs). The proposed BIM adoption model assesses BIM implementation benefits, costs and challenges faced by SMOs. This study is aimed to providing the development and implementation of BIM.

Reviewing the available literatures for past one decade, it has been observed that, attempts to reduce embodied energy or operational energy were made separately and only in terms of selecting or replacing specific alternative building materials. No researchers have attempted to take a specific case study of infrastructure building facility to reduce its operational and embodied energy for the whole built asset. Further, it has been observed that very nominal attempt has been made by researchers to work on operational and embodied energy together. Either researchers have worked and made attempts to reduce operational energy or researchers have worked to reduce embodied energy. Hence, the present research aims in developing a methodology for reduction of operational and embodied energy by considering an infrastructure building facility which is quite complex in nature, like a metro rail station for elevated metro rail corridor construction.

III. CASE STUDY

The case study undertaken for the present research is the elevated metro rail station box located in Ahmedabad. Phase-1under construction consists of North-South corridor of 18.87 km and East-West corridor of 21.16 km totalling to 40.03 km in which 33.50 km section is elevated, while rest 6.53 km is underground. Hence out of total 32 stations, 28 are elevated, and 4 are underground as it passes through highly traffic-congested area. Table 1 shows the other project and stakeholder details of the case study. Figure 1 shows the alignment, location, and route of all the stations with respect to their directional corridors.

Sr. No.	Details	
1	Project Name	Elevated metro rail station box Ahmedabad
2	Estimated Cost	400 million INR
3	Contractor	RanjitBuildcon
4	Client	GMRC (formerly MEGA) On North-South Corridor Of Ahmedabad
5	Time Period	21 months
6	Total Carpet Area	5740 sq.m
7	MEPF (Mechanical, Electrical, Plumbing, and Fire- safety) Consultant	Siemens India-Siemens AG, Germany
8	Architect	Aarvee Associates JV With K.P. Padmanabha& Associates.
9	Structural Designer	Aarvee Associates JV With K.P. Padmanabha& Associates.
10	PMC (Project Management Consultancy)	Systra-RITES-Oriental-AECOM JV

Table 1 Project details of elevated metro rail station of Ahmedabad metro rail project phase-1

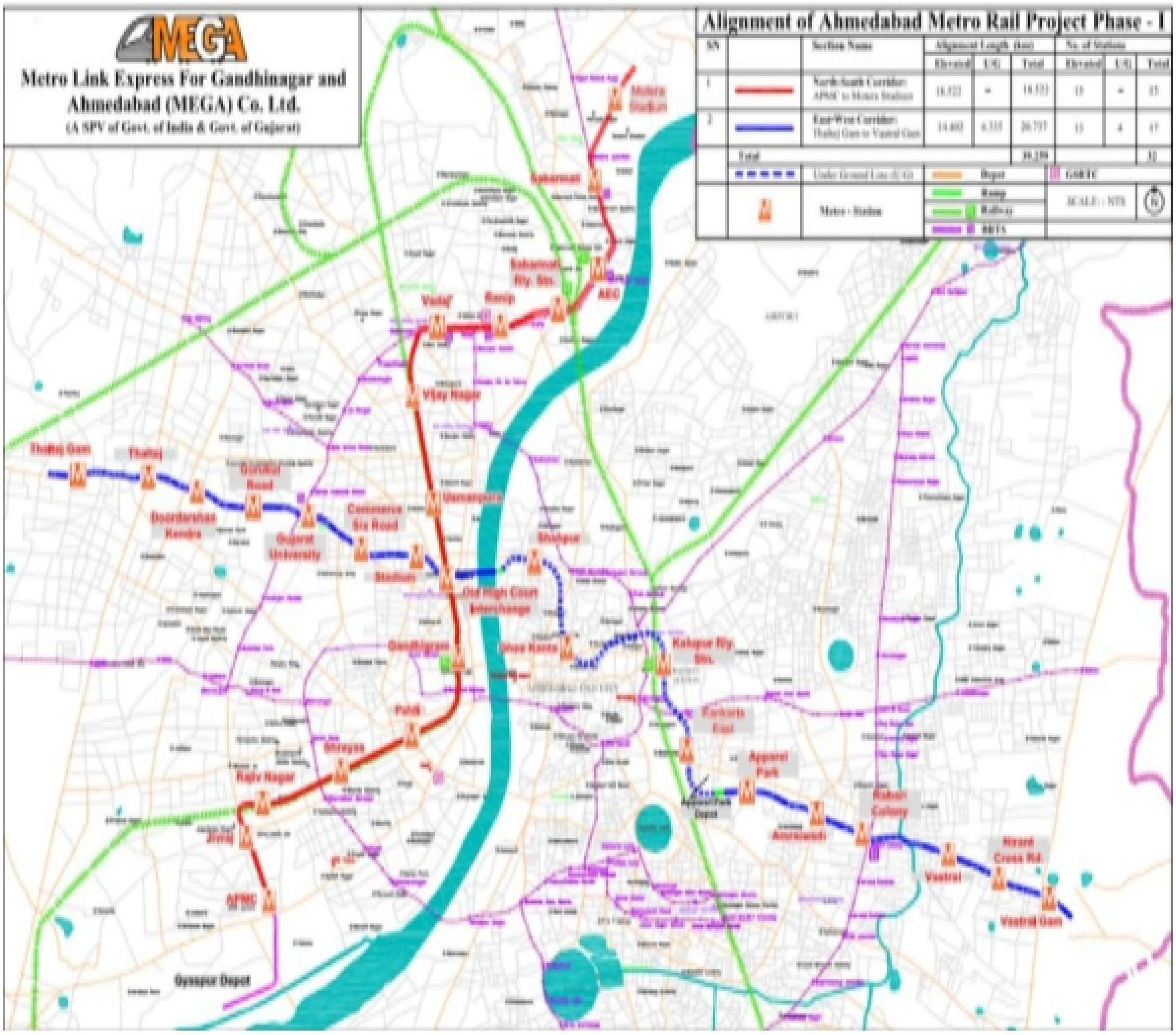

Figure 1 Location and route alignment details of Ahmedabad metro rail project phase-1

IV. METHODOLOGY AND CONCEPTUAL FRAMEWORK

Several methodologies have been developed for estimating energy consumption. Some of them are based on statistics, while others are based on simulations. In general, it is accepted that weather data must be given careful attention and consideration in forecasting the energy consumption of buildings. Providing the drawing plans and materials specifications of the case study building, the building is simulated in Revit Architecture 2018 software. After the simulation, for integrating between Revit and Energy Modelling tool (Green Building Studio), zones must be formed for creating various parts of the building. Without creating zones in Revit architecture, the energy of the building's various spaces cannot be modelled. In fact, the file cannot be exported to Green Building Studio software. After creating zones, for exporting the simulation file from Revit to Green Building Studio, the gbXML based export way explained in the next parts must be used. This is the way that can export all building's specifications defined in Revit to Green Building Studio. By choosing gbXML based export, some basic and necessary assumptions for energy modelling such as location and types of the building must be established. After considering essential assumptions, the file is exported to the Green Building Studio software for energy modelling and analysis.

Before implementing the export process, rooms known as zones must be produced to separate operational spaces of the building required for energy simulation in Green Building Studio. The other application of the room element is to specify the area and volume of the spaces. In addition to room setting within BIM before exporting the energy model, the location and types of the building must also be defined, since they are significant factors in energy use and can affect the amount of energy consumed. Figure 1shows the perspective of an export gbXML file, and the colours displayed in the model describe surface elements. Table 2 shows the various zones of the metro rail station box for energy analysis.

Sr. No.	Zones	Assumptions
1	Ticket Area	Number of people involved: 120 Type of system: cooling only
		Environmental temperature range for comfort: 27°C Standard operation duration: 24hr/day
2	Staff Room	Number of people involved: 7 Type of system: cooling only
		Environmental temperature range for comfort: 27°C Standard operation duration: 24hr/day
3	Security Check Area	Number of people involved: 120 Type of system: cooling only
		Environmental temperature range for comfort: 27°C Standard operation duration: 24hr/day
4	Entry Area	Number of people involved: 266 Type of system: cooling only
		Environmental temperature range for comfort: 27°C Standard operation duration: 24hr/day
5	Exit Area	Number of people involved: 266 Type of system: cooling only
		Environmental temperature range for comfort: 27°C Standard operation duration: 24hr/day
6	Passenger & Boarding Area	Number of people involved: 1000 Type of system: cooling only
		Environmental temperature range for comfort: 27°C Standard operation duration: 24hr/day
7	Station Control Room	Number of people involved: 8 Type of system: cooling only
		Environmental temperature range for comfort: 27°C Standard operation duration: 24hr/day
8	Store Room	Number of people involved: 5 Type of system: cooling only
		Environmental temperature range for comfort: 27°C Standard operation duration: 24hr/day
9	Signalling & Telecom Room	Number of people involved: 10 Type of system: cooling only
		Environmental temperature range for comfort: 27°C Standard operation duration: 24hr/day
10	Rest Rooms	Number of people involved: 12 Type of system: cooling only
		Environmental temperature range for comfort: 27°C Standard operation duration: 24hr/day
11	Station Manager Room	Number of people involved: 4 Type of system: cooling only
		Environmental temperature range for comfort: 27°C Standard operation duration: 08hr/day
12	Maintenance Area	Number of people involved: 8 Type of system: cooling only
		Environmental temperature range for comfort: 27°C Standard operation duration: 24hr/day
13	Solar Battery Area	Number of people involved: 4 Type of system: cooling only
		Environmental temperature range for comfort: 27°C Standard operation duration: 24hr/day
14	Ups Battery Room	Number of people involved: 4 Type of system: cooling only
		Environmental temperature range for comfort: 27°C Standard operation duration: 24hr/day
15	Food Court	Number of people involved: 8 Type of system: cooling only
		Environmental temperature range for comfort: 27°C Standard operation duration: 18hr/day

Table 2 Assumptions for various zones of metro rail station box for energy analysis

After entering to Green Building Studio, it could be seen that it can identify those elements simulated in Revit. It shows that these software products can be integrated to facilitate simulation and analysis. Before starting the analysis, we can evaluate the building's shadow on various days of the year and also various times of a specified day. First, weather specification of the building must be loaded based on its location, since different locations have different sun paths and conclusively dissimilar shadow positions. After considering the weather location of Ahmedabad, India, the daily and annual sun path can be visualized. This allows the visual interpretation of exactly where the sun is and its impacts on the various parts of the building during different times of the day. It can also be helpful in visualizing the building's shadow throughout an entire day.

V. CASE ANALYSIS

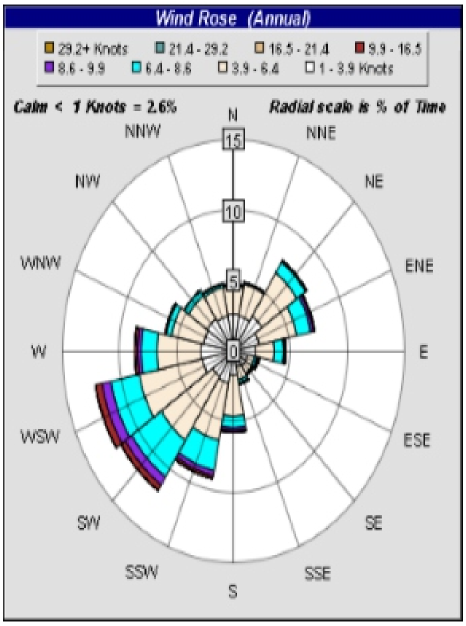

Figure 2 Wind Ross diagram (Annual) for metro rail station

The above wind diagram (figure 3) demonstrates the wind speed in knots and wind direction at a particular location over a period of time. Typically the wind direction data is sorted into twelve equal arc segments, 30° each segment, in preparation for plotting a circular graph in which the radius of each of the twelve segments represents the percentage of time that the wind blew from each of the twelve 30° direction segments. The wind rose above shows that during this period, the wind blew from West-South-West & South-West 10-15% of the time and North- East & East-North-East 5-10% of the time.

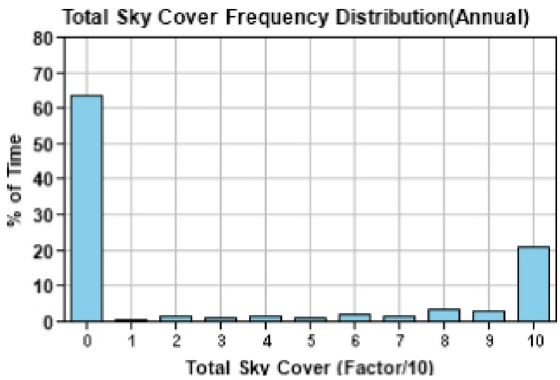

Figure 3 annual sky cover with respect to percent of the time for metro rail station

The above bar chart (figure 4) shows the amount of time (in percentage), the total sky is enclosed with full or partial sunlight cover. The Total sky cover factor ranges from 0 to 10, denoting maximum daylight at 0 and minimum on 10. In the above figure, it can be clearly seen that 60%, which is the highest of the time, the sky is exposed to 0 sky factor and the 10 sky-factor is the second highest for 20% of time. To recapitulate, the sky over the location has a clear unobstructed view without obstructions of clouds most of the time.

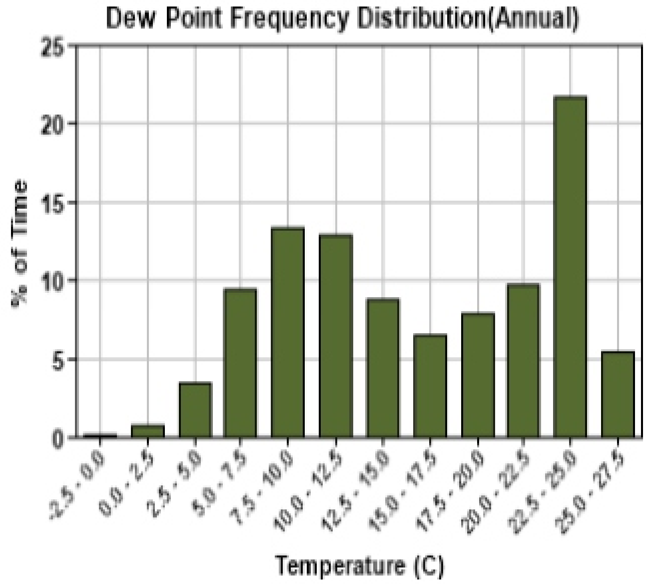

Figure 4 Annual Dew point with respect to percent of time for metro rail station

Figure 5 shows the annual dew point distribution frequency with respect to temperature. Here, the X-axis represents the temperature starting from -2.5° Celsius to maximum of 27.5° Celsius at an interval of 2.5° Celsius. Here, the Y-axis represents the percentage of time dew is present at a particular temperature. It gives an idea of the dew befalling at a certain temperature. The maximum percentage of time dew occurs at temperature 22.5° Celsius to 25° Celsius and the minimum is at 0° Celsius. To conclude, the above bar chart shows the fluctuating trend of dew point at the location.

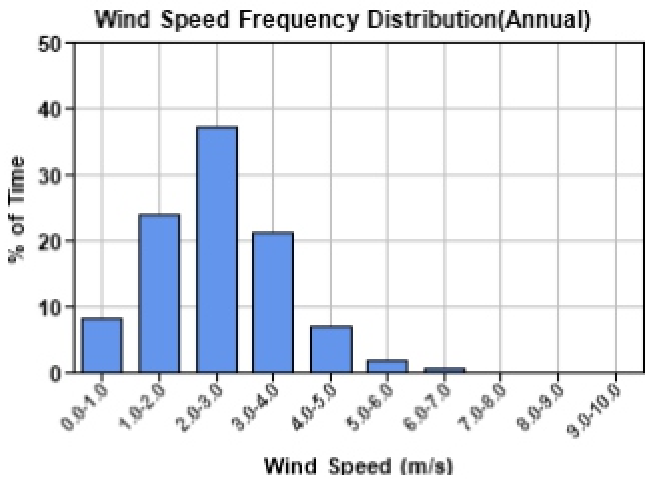

Figure 5 Annual wind speed distribution with respect to percent of the time for metro rail station

The above bar chart is the histogram representing wind speed classes and the frequency of hours per year that are expected for each wind speed class. It illustrates the wind speed frequency distribution with respect to the total time. Here, the X-axis represents the wind speed starting from 0m/sto maximum of 10m/s at an interval of 1m/s. Here, the Y-axis represents the percentage of time a particular wind speed blows annually. It gives an idea of maximum wind speed that would affect the location. Maximum time the wind speed of 2 -3 m/s occurs, which is 40%. Moreover the lowest amount of wind speed affecting the location is 10 m/s.

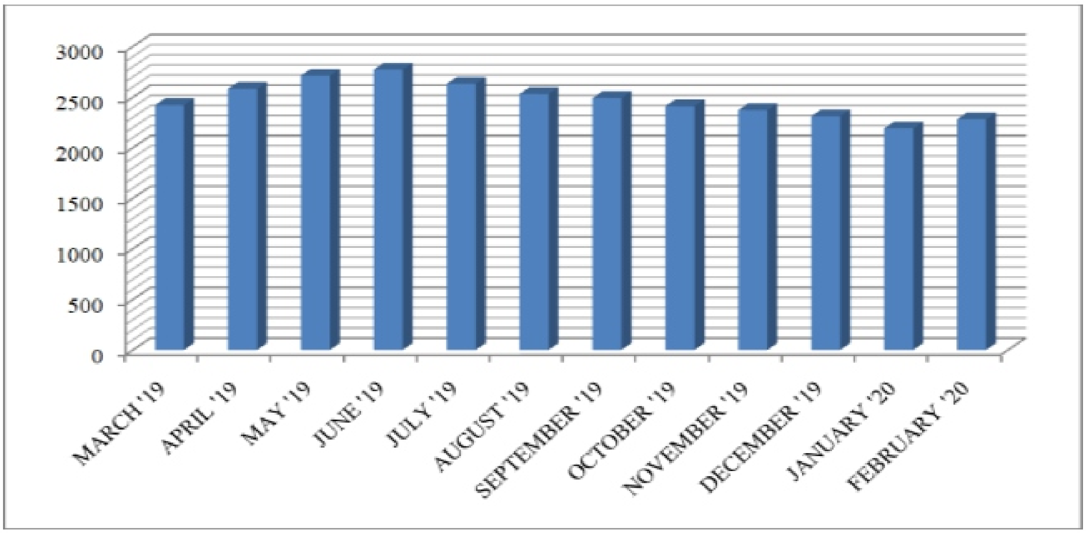

Figure 6 monthly energy consumption for cooling load Kw/Day for metro rail station

In the above figure, by considering all months, it is seen that the energy used throughout the year to keep the building's temperature to 27° C based on these materials was 29,690 kWh. As shown in figure 7, there is just a cooling load for all months of a year due to the location of the building in Ahmedabad India, which is a very hot and humid area. It shows that there is just a cooling load for this building. As it can be seen, the highest amount of energy consumption occurs in May, June, and July. On the other hand, energy consumption in January and February is the lowest, at about 2190 and 2280 kWh/Day, respectively. All of these analyses are based on a strong database in Green Building Studio analysis software in which the weather specifications of all regions around the world have been established.

Name of building component in the various rooms	Existing materials used
Floor	Cement Concrete Floor
	Anti-Skid Vitrified
	Honed Granite Floor
Wall	Granite Cladding
	Vitrified Tiles
	Plaster with Acrylic Emulsion Paint
Ceiling	Perforated Metal Ceiling
	Plaster with Acrylic Emulsion Paint

Table 3 Details of building materials for building components of the elevated metro rail station

The energy consumption was determined based on the baseline design, including the existing material specifications of the building. Then, alternative materials were used to replace the baseline design to investigate their impacts on reducing and/or increasing energy consumption. Finally, a set of higher performance materials was recommended for the purpose of reducing the energy consumption of the building, which will lead to reduction of embodied energy and carbon dioxide emissions. Therefore all these existing materials which are utilized in the construction of the elevated metro station box were considered as baseline materials based on which alternative materials were analyzed and recommended to improve energy building performance throughout the entire project life cycle. Table 3 and Table 4 shows the dimensions and building materials details involved in the construction of the elevated metro rail station box with respect to their building components.

VI. RESULTS AND DISCUSSION

FLOOR						
Sr. No.	Existing	Embodied Energy (MJ/m^2)	Alternate	Embodied Energy (MJ/m^2)	Percentage of energy savings	Remark
1	Cement Concrete Floor	1.9	Unchanged	1.9	0%	
2	Anti-Skid Vitrified	8.2	Stone floor tile	0.44	94.63%	
3	Honed Granite Floor	13.9	Polished Kota Stone	3.7	73.38%	

Table 4 Alternatives for Floor

Floor Modification

In this study, two alternative components are contemplated for the floor, i.e., Anti-Skid vitrified and Honed Granite Floor. So, the Stone floor tile and Polished Kota Stone were replaced by these types of materials to investigate their capability of reducing energy consumption. And cement concrete flooring was kept unchanged. As shown in Table 5, there was about 7-8 MJ/m2 difference between the baseline floor and the two alternative floors.

WALL						
Sr. No.	**Existing**	**Embodied Energy (MJ/m^2)**	**Alternate**	**Embodied Energy (MJ/m^2)**	**Percentage of energy savings**	**Remark**
1	Granite Cladding	13.9	Polished Kota Stone Cladding	3.7	73.38%	3.6 – Light wt. Concrete Block 1.1 – Cement Mortar 61.5 – Cement Mortar
2	Vitrified Tiles	8.2 + 3.6 + 1.1 = 12.9	Stone floor tile	0.44 + 3.6 +1.1= 5.14	60.15%	
3	Plaster with Acrylic Emulsion Paint	61.5 + 4.8 + 3.6 = 69.9	Ferro Cement Wall Panel	2.3	96.70%	

Table 6 Alternatives for Wall

Wall Modification

Granite Cladding, Vitrified Tiles, Plaster with Acrylic Emulsion Paint was replaced as the wall component of the building by alternative materials, such as Polished Kota Stone Cladding, Stone floor tile, and Ferro Cement Wall Panel respectively to identify a material with better performance while retaining the original structure of the building. Table 6 indicates the amount of energy used annually based on the baseline design and the use of alternative materials as the wall component.

CEILING						
Sr. No.	Existing	Embodied Energy (MJ/m^2)	Alternate	Embodied Energy (MJ/m^2)	Percentage of energy savings	Remark
1	Perforated Metal Ceiling	330	Toughened Fiber Glass	23.5	92.87%	3.6 – Light wt. Concrete Block 4.8 – Cement Plaster
2	Plaster with Acrylic Emulsion Paint	4.8 + 61.5 + 3.6 = 67.1	Ferro Cement Roof Panel	2.3	96.57%	

Table 7 Alternatives for Ceiling

Ceiling Modification

By using Toughened Fiber Glass and Ferro Cement Roof Panel in the ceiling, the annual operational energy consumption was reduced by about 306.5 MJ/m2, considerably more than reductions achieved by the other modifications. Table 7 demonstrates the operational energy consumption based on two different compositions of materials in the ceiling.

In a nut shell, considering the temperature necessities in NBC, i.e., 27°C, Wind rose, and temperature diagrams, orientation of openings can be adjusted to get the maximum benefit of natural air circulation and ventilation. Also, the better alternative materials are selected of translucent property to let a maximum of the daylight to enter into the station box leading towards the reduction in artificial lighting fixtures and lower energy demand. The energy consumed annually is statistically studied and materials are suggested for alternative baseline material.

VII. CONCLUSION

The study was conducted for the case study undertaken, i.e., elevated metro rail station located in Ahmadabad. The results of the study help the design consultancy to use BIM as a tool to generate best in class energy-efficient metro rail station by a sustainable approach in the future. The Government shall take an initiative to encourage the AECO industry to utilize BIM tool in the design phase of the project leading towards identification and resolution of any potential or possible clashes or issues which might take place during execution phase. It shall be involved in the research and training as it plays a significant role in the smooth and successful completion of the complex infrastructure projects.

Energy simulation investigates building performance virtually in the design phase, which facilitates the stakeholders of the project to decide the building specifications having minimal effect on the environment. In the AECO industry, BIM proves to be an effective tool to the designers in designing optimum and best in class building design and orientations. BIM shall be considered for energy simulation to measure and improve building performance in the design phase only.

Further, this incorporation of BIM in the design phase could be utilized to generate energy-efficient designs and reduce the rework minimizing time and cost overrun. This is an effort for reducing and optimizing the energy demand and consumption, and also the prevention measures for harmful impact on the environment showthe benefits in terms of energy- efficient and sustainable infrastructure. Hence, BIM technology shall be incorporated by the project stakeholders for effective solutions in reducing operational and embodied energy consumption.

REFERENCE

[1] Ahuja, R. S. A. A. M., 2018. Developing organizational capabilities to deliver lean and green project outcomes using BIM. Engineering, Construction and Architectural Management, 25(10), pp. 1255-1276.

[2] Anderson, H. K. K., 2013. Energy Modeling System Using Building Information Modeling Open Standards. Journal of Computing in Civil Engineering, Volume 27, pp. 203-211.

[3] Azhar, S. B. J., 2009. BIM for sustainability analysis. International Journal of Construction Education and Research, 5(4), pp. 276-292.

[4] B. Zhang, Y. L. R. R. V. K., 2016. Invariant probabilistic sensitivity analysis for building energy models. Journal of building performance simulation, 10(4), pp. 392-405.

[5] Bashar, A. N. S. Y., 2018. Review of BIM literature in construction industry and transtortation: meta-analysis. Construction innovation, 18(4), pp. 433-452.

[6] Betul, B. E. U. T. A., 2009. Prediction of building energy consumption by using artificial neural network. Advances in Engineering Software, 40(5), pp. 356-362.

[7] Cheng, Z. R. S. N. L. T., 2018. BIM-based investigation of total energy consumption in delivering building T products. Advanced Engineering Informatics, Volume 38, pp. 370-380.

[8] Chong, H.-Y. F. S.-L. S. M. H. S.-H. T. C.-M., 2017. Preliminary contractual framework for BIM-enabled projects. Journal of Construction Engineering and Management, 143(7).

[9] Dat, T. D. A. G. N. N. A. G. T. Z. J. T., 2019. Examining Green Star certification uptake and its relationship with Building Information Modelling (BIM) adoption in New Zealand. Journal of Environmental Management, Volume 250, pp. 1-11.

[10] Edirisinghe, R. a. L. K., 2015. Comparative analysis of international and national level BIM standardization efforts and BIM adoption. Eindhoven, The Netherlands, s.n., pp. 1507-1513.

[11] González-Gil, A. P. R. B. P., 2015. Optimal energy management of urban rail systems: Key performance indicators. Energy Conversion and Management, Volume 90, p. 282–291.

[12] Hernandez, P. K. P., 2008. Defining zero energy buildings. A life cycle perspective. Dublin, Ireland, PLEA - 25th conference on passive and low energy architecture.

[13] Hirakraj, B. D. S., 2019. 6D Energy Efficient Metro Rail Station Design Using BIM: A Review of Literature. Oxford, International Conference on Innovative Applied Energy.

[14] Hong, Y. H. A. S. S. A. A., 2019. BIM adoption model for small and medium construction organisations in Australia. Engineering, Construction and Architectural Management, 26(2), pp. 154-183.

[15] Hong, Y. H. A. S. S. a. A. A., 2019. BIM adoption model for small and medium construction organisations in Australia. Engineering, Construction and Architectural Management, 26(2), pp. 154-183.

[16] Huaquan, Y. S. L., 2019. An algorithm to facet curved walls in IFC BIM for building energy analysis. Automation in Construction, Volume 103, pp. 80-103.

[17] International Finance corporation, 2017. Indian Construction Material Database of embodied energy and Global Warming Potential Methodology Report, European Union: International Finance Corporation.

[18] Joblot, L. P. T. D. D. L. L., 2017. Literature review of Building Information Modeling (BIM) intended for the purposeof renovation projects. International Federation of Automatic Control, 50(1), pp. 10518-10525.

[19] Jones, G. P. H. C. I., 2008. Embodied energy and carbon in construction materials. energy, 6(2), pp. 87-98.

[20] José, P. C. L. B. R. M., 2019. Optimising building sustainability assessment using BIM. Automation in Construction, Volume 102, pp. 170-182.

[21] Kamar, A. A. P. F. R., 2016. Energy analysis using cooperation between BIM tools (Revit and Green Building Studio) and EnergyPlus. Portugal, Congresso Português de Building Information Modelling.

[22] Khasreen, M. B. P. a. M. G., 2009. Life-cycle assessment and theenvironmental impact of buildings: a review. Sustainability, 1(1), pp. 674-701.

[23] L.C.Ng. Persily, A. E. S., 2015. Improving infiltration modelingin commercial building energy models. Energy Building, Volume 88, pp. 316-323.

[24] M.Y. Han, G. C. L. S. J. L. A. A. B. A., 2013. Embodied energy consumption of building construction engineering: case study in E-town, Beijing. Energy Building, Volume 64, pp. 62-72.

[25] Manish, K. D. J. L. S. L. C. H. C., 2006. Identification of parameters for embodied energy measurement: A literature review. Energy and Building, Volume 42, pp. 1238-1247.

[26] Mark, K. X. C. H. Y. L. L. P. T. L., 2019. A review and outlook for integrated BIM application in green building assessment. Sustainable Cities and Society, Volume 48, pp. 1-13.

[27] Mojtaba, V. S. M. V. S. A. B. A. S. B., 2015. Reducing the operational energy demand in buildings using building information modeling tools and sustainability approaches. Ain Shams Engineering Journal, Volume 6, pp. 41-55.

[28] Nii, A. M. A. E. K. C., 2014. Architect's perception on the challenges of building energy efficiency in Ghana. Structural Survey, 32(4), pp. 365-376.

[29] Ozorhon, B. K. U., 2016. Critical success factors of building information modeling implementation. Journal of Management in Engineering, 33(3), pp. 1-10.

[30] Pezeshki, Z. S. A. D. A., 2019. Application of BEM and using BIM database for BEM: A review. Journal of Building Engineering, Volume 23, pp. 1-17.

[31] Poorang, P. E. R. F. A. H. Z. S. T. I. S. K. R. J., 2019. Facilitating Building Information Modelling (BIM) using Integrated Project Delivery (IPD): A UK perspective. Journal of Building Engineering, Volume 26, p. 100907.

[32] Qing-Hua, H. Q. L. D. Y. Y.-K. L., 2012. Current situation and barriers of BIM implementation Vol. 2012 No. 1, pp. 73- 76.. Journal of Engineering Management, 2012(1), pp. 73-76.

[33] Ramesh, T. P. R. a. S. K., 2010. Life cycle energy analysis of buildings: an overview. Energy and Buildings, 42(42), pp. 1592-1600.

[34] Richard, G. R. S. J. W., 2005. The increasing importance of sustainability for building ownership. Journal of Corporate Real Estate, 7(4), pp. 339-350.

[35] Sartori, I. H. A., 2007. Energy use in the life cycle of conventional and low-energy buildings: a review article. Energy and Buildings, Volume 39, pp. 249-257.

[36] Sergio, P. R. W. a. o., 2018. MVD based information exchange between BIM and building energy performance simulation. Automation in Construction, Volume 90, pp. 91- 103.

[37] Shem, H. D. J. S., 2008. Using building energy simulation and geospatial modeling techniques to determine high resolution building sector energy consumption profiles. Energy and Buildings, 40(8), pp. 1426-1436.

[38] Smith, P., 2014. BIM implementation – global strategies. Procedia Engineering, Volume 85, pp. 482-492.

[39] Theophilus, O. O. E. W. I. L., 2019. BIM for construction education: Initial finding from a litrature review. Tallinn, Estonia, 10th Nordic Conference on Construction Economics and Organization, pp. 305-313.

[40] Thomas, O. J.-U. S., 2009. Building energy parameter investigations based on multivariate analysis. Energy and Buildings, 41(1), pp. 71-80.

[41] Tiberiu, C. J. V. E. B., 2008. Development and validation of regression models to predict monthly heating demand for residential buildings. Energy and Building, 40(10), pp. 1825- 1832.

[42] Treloar, G. M. A. L. P. a. I. U., 1999. Embodied energy analysis of fixtures, fittings and furniture in office buildings. Facilities, 17(11), pp. 403-410.

[43] Tuomas, L. R. H. A. K., 2007. Benefits of BIM in the Thermal Performance Management. Finland, Building Simulation.

[44] Venkatarama, R. J. K., 2003. embodied energy of common and alternate building material aand technologies. energy and buildings, Volume 35, pp. 129-137.

[45] Westfall, L. N. M. T. G., 2003. Estimating the impacts of voluntary programs: results from a recent study on the Canadian industry program for energy conservation. Washington, DC, ACEEE summer Study on eneergy efficiency in industry.

[46] Yaser, G. I. A. R., 2019. Awareness and challenges of building information modelling (BIM) implementation in the Yemen construction industry. Journal of Engineering design and technology, 17(5), pp. 1077-1084.

[47] Yewande, A. A. A. A. N. B. P. T. N., 2019. Energy efficiency practices in facilities management in Johannesburg. Journal of Facilities Management, 17(4), pp. 331-343.

[48] Yiqun, P. R. Y. Z. H., 2008. Energy modeling of two office buildings with data center for green building design. Engergy and Building, 40(7), pp. 1145-1152.

[49] Yung, P. L. K. Y. C., 2013. An audit of life cycle enery analyses of buildings. Habitat International, 39(1-8), pp. 43- 54.

[50] Zaid, A. P. J., 2014. The importance of embodied energy in carbon footprint assessment. Structural Survey, 32(1), pp. 49- 60.

[51] Zhou, Y. Y. Y. a. Y. J., 2019. Barriers to BIM implementation strategies in China. Engineering, Construction and Architectural Management, 26(3), pp. 554- 574.

APPENDIX

Sr. No.	Room code	Room	Floor	Wall	Ceiling	Skirting	Door	Weight (mm)	Height (mm)	Remarks
1	R-01	ASS/TSS	52 mm Cement concrete floor with concrete hardener topping	Plaster with Acrylic Emulsion Paint			FD2	2050	2450	2 hour Fire rated door with vision panel (double leaf door)
							FD4	1050	2150	2 hour Fire rated door with vision panel (double leaf door)

2	R-02	Battery UPS	52 mm Cement concrete floor with concrete hardener topping	Plaster with Acrylic Emulsion Paint			FD1	1850	2450	2 hour Fire rated door with vision panel (double leaf door)
3	R-03	Ticket office/ ass side	FALSE FLOOR 300mm. 20 mm Polished Granite (Honed)	Plaster with Acrylic Emulsion Paint	600x600 perforated meted ceiling		D4	1050	2150	Normal door
4	R-04	Solar battery Room-01	600X600 VITRIFIED	Plaster with Acrylic Emulsion Paint	Plaster with Acrylic Emulsion Paint	150 mm VITRIFIED	FD4	1050	2150	1 hour Fire rated door with vision panel (single leaf door)
5	R-05	Solar battery Room-02	600X600 VITRIFIED	Plaster with Acrylic Emulsion Paint	Plaster with Acrylic Emulsion Paint	150 mm VITRIFIED	FD4	1050	2150	1 hour Fire rated door with vision panel (single leaf door)
6	R-06	EFO	FALSE FLOOR 300mm	Plaster with Acrylic Emulsion Paint	600x600 perforated metal ceiling		-	1050	2150	Partly Glazed door
7	R-07	Station Control room	FALSE FLOOR 300mm	Plaster with Acrylic Emulsion Paint	600x600 perforated meted ceiling		-	1250	2150	Partly Glazed door
8	R-08	SECURITY ROOM	600X600 VITRIFIED	Plaster with Acrylic Emulsion Paint	Plaster with Acrylic Emulsion Paint	150 mm VITRIFIED	D2a	1050	2150	Normal door
9	R-09	SCR STORE	600X600 VITRIFIED	Plaster with Acrylic Emulsion Paint	Plaster with Acrylic Emulsion Paint	150 mm VITRIFIED	FD4	1050	2150	1 hour Fire rated door
10	R-09.1	Store	600X600 VITRIFIED	Plaster with Acrylic Emulsion Paint	Plaster with Acrylic Emulsion Paint	150 mm VITRIFIED	FD4	1050	2150	1 hour Fire rated door
11	R-10	Ticket Office	FALSE FLOOR 300mm. 20 mm Polished Granite (Honed)	Plaster with Acrylic Emulsion Paint	600x600 perforated meted ceiling		D4	1050	2150	Normal door
12	R-11	Signalling Equipment room	FALSE FLOOR 450mm	Plaster with Acrylic Emulsion Paint	600x600 perforated metal ceiling		FD1	1850	2450	2 hour Fire rated door with vision panel (double leaf door)
13	R-12	Telecom Equipment room	FALSE FLOOR 450mm	Plaster with Acrylic Emulsion Paint	600x600 perforated meted ceiling		FD1	1850	2450	2 hour Fire rated door with vision panel (double leaf door)
14	R-13	PSD	FALSE FLOOR 450mm	Plaster with Acrylic Emulsion Paint	600x600 perforated metal ceiling		FD3	1250	2150	2 hour Fire rated door with vision panel (double leaf door)
15	R-14	Ups battery room	Acid Alkali resistant Vitrified tiles 600×600	Plaster with Acrylic Emulsion Paint	600x600 perforated meted ceiling	150 mm VITRIFIED	FD1	1850	2450	2 hour Fire rated door with vision panel (double leaf door)
16	R-15	ANTE ROOM	Filled Floor (Foam Concrete) + Granite Floor	Plaster with Acrylic Emulsion Paint	600x600 perforated metal ceiling	150 mm granite	FD2	2050	2450	2 hour Fire rated door with vision panel (double leaf door)
17	R-16	Staff room	600X600 VITRIFIED	Plaster with Acrylic Emulsion Paint	600x600 perforated meted ceiling	150 mm VITRIFIED	D2	950	2150	Normal door
18	R-17	Toilet	Granite floor	Granite Cladding			D3	950	2150	Normal door
19	R-17.1	Male	600X600 ANTI SKID VITRIFIED	VITRIFIED TILES 100 mm above false ceiling	600x600 perforated meted ceiling		D5	750	2150	
20	R-17.2	Handicapped	600X600 ANTI SKID VITRIFIED	VITRIFIED TILES 100 mm above false ceiling	600x600 perforated metal ceiling		D3a	1050	2150	
21	R-17.3	Female	600X600 ANTI SKID VITRIFIED	VITRIFIED TILES 100 mm above false ceiling	600x600 perforated meted ceiling		D5	750	2150	

22	R-18	Cleaner	600X600 VITRIFIED	1200 mm high VITRIFIED TILES Cladding*Plaster with Acrylic Emulsion Paint			D2a	1050	2150	Normal door
23	R-19	Refuge	600X600 VITRIFIED	1200 mm high VITRIFIED TILES Cladding*Plaster with Acrylic Emulsion Paint			FD4	1050	2150	1 hour Fire rated door with vision panel (single leaf door)
24	R-20	Station manager room	600X600 VITRIFIED	Plaster with Acrylic Emulsion Paint	600x600 perforated metal ceiling	150 mm VITRIFIED	D2	950	2150	Normal door
25	R-21	Telecom operator room	600X600 VITRIFIED	Plaster with Acrylic Emulsion Paint	600x600 perforated meted ceiling	150 mm VITRIFIED	D2	950	2150	Normal door
26	R-22	Signalling maintenance room	600X600 VITRIFIED	Plaster with Acrylic Emulsion Paint	600x600 perforated metal ceiling	150 mm VITRIFIED	D2	950	2150	Normal door
27	R-23	Permanent way store		Plaster with Acrylic Emulsion Paint		150 mm VITRIFIED	D2b	1250	2150	Normal door
28	R-24	Crew control	600X600 VITRIFIED	Plaster with Acrylic Emulsion Paint	600x600 perforated metal ceiling	150 mm VITRIFIED	D2	950	2150	Normal door
29	R-25	Crew booking office	600X600 VITRIFIED	Plaster with Acrylic Emulsion Paint	600x600 perforated meted ceiling		D2	950	2150	Normal door
30	R-26	Train operator male	600X600 VITRIFIED	Plaster with Acrylic Emulsion Paint	600x600 perforated metal ceiling	150 mm VITRIFIED	D2	950	2150	Normal door
31	R-27	Train operator female	600X600 VITRIFIED	Plaster with Acrylic Emulsion Paint	600x600 perforated meted ceiling	150 mm VITRIFIED	D2	950	2150	Normal door
32	R-28	Loading & unloading platform/ASS-TSS	52 mm Cement concrete floor with concrete hardener topping	Plaster with Exterior Grade Acrylic Emulsion Paint		150mm cement skirting				
33	R-29	A.C outdoor Unit	52 mm Cement concrete floor with concrete hardener topping	Plaster with Exterior Grade Acrylic Emulsion Paint		150mm cement skirting1850	D2c	1850	2150	Normal door
34	R-30	Pump room	52 mm Cement concrete floor with concrete hardener topping	Plaster with Acrylic Emulsion Paint	Plaster with Acrylic Emulsion Paint		FD5	1250	2150	1 hour Fire rated door with vision panel (single leaf door)
35	R-30.1	Sump	Water proofing	Water proofing	Water proofing					
36	R-31	Refuge store room at grade	600X600 VITRIFIED	1200 mm high VITRIFIED TILES Cladding*Plaster with Acrylic Emulsion Paint			FD4	1050	2150	1 hour Fire rated door (single leaf door)
37	R-32	D.G	52 mm Cement concrete floor with concrete hardener topping		Plaster with Exterior Grade Acrylic Emulsion Paint					Rolling shutter
38	R-33	Toilet at Platform					D3a	1050	2150	
39	R-33.1	Male	600X600 ANTI SKID VITRIFIED	VITRIFIED TILES	Plaster with Acrylic Emulsion Paint		D3a	1050	2150	
40	R-33.2	Female	600X600 ANTI SKID VITRIFIED	VITRIFIED TILES	Plaster with Acrylic Emulsion Paint		D3a	1050	2150	
41		Paid concourse	20 mm Honed granite floor	20 mm Polish Granite Cladding						
42		Unpaid concourse	20 mm Honed granite floor	20 mm Polish Granite Cladding						
43		Entry Structure	20 mm Honed granite floor	20 mm Polish Granite Cladding						
44		Platform	20 mm Honed granite floor	Painting						

Sr. No.	Common items	Rolling shutter	Door	Remarks
1	Ass &Tss room	3500 × 3500		
2	Entry at concourse level	4000 × 3000		
3	Entry at road level	3500 × 3500		
4	Shaft door		750 × 2150	
5	Shaft door		650 × 650	
6	Shaft door		450 × 1550	Fire rating of electrical shaft & door as per code
7	Door for passage to non-operation rooms		1050 × 2150	Normal

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An Analytical and Experimental Study of Well Foundation

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A B S T R A C T

Bridges, though a man made structure, over a period of time become an important part of environment because in most of the cases water flowing below is used for drinking, irrigation and underground recharging. The alluvial region of India spread from Punjab to West Bengal has a peculiar nature because soil is almost soft in nature consisting of mainly sand, clay and silt which is fertile for vegetation. Water retention and its movement condition are high throughout the year. Several type of water bodies which exists in this type of region are pond, small drain, small and medium rivers which drains into the big rivers like Ganga, Yamuna, Ghahgra, Gomti and Sai etc.Since long time, road system on the earthen track and pucca has been introduced for traffic like chart, chariot and motorised vehicle. There were little number of bridges over major rivers i.e. bridge alone to cross over the river Ganga except in few places like Allahabad, Kanpur and Varanasi and over the Ghaghra Algine bridge, Maghighat, Bhatni. Some bridges were constructed over small and medium rivers in medevial period by local rulers and business men which have now become obsolete. It is found that most of the bridges are of masonry arches wooden and trusses having insufficient water and carriage way. After independence, the road network system has been improved to meet out socio economic needs of people. The new bridges have been constructed with standard road width and sufficient water way. Study has been conducted for existing new constructed bridge system over small river and alluvial region of Uttar Pradesh to set guidance for future course of action in replacing and providing new bridges to optimise the needs of the people. For this purpose, study has been conducted for sustainable option of minor bridges over small rivers discharge upto 410 m3/s. It is found that the well foundation bridge on medium type river is more efficient and economical than other type of foundation such as pile foundation, raft foundation.

I. INTRODUCTION

A bridge is a structure provided over an obstacle such as river, road, valley, railway etc. With the advancement in civil engineering several types of bridges are constructed like beam, truss, cantilever, cable stayed and suspension bridges. According to IRC the bridges have been classified in three types culvert, minor bridges and major bridges depending upon their length. For culvert the span length upto 6m, minor bridge length is above 6m and maximum upto 60m and major bridges the length is above 60m. The design of bridge constructed depending on the function of bridge, nature of terrain where bridge is constructed, the material used to make it and the funds available to build it. In this study the main objective is to understand the design and cost study has done and found well foundation minor bridges are economical and easy in construction.

II. ANALYTICAL STUDY

For the study the bridge on well foundation design data of 5×15 m is given below:-

Design Data

1. Design discharge (Q) = 410 m^3/sec
2. Highest flood level (H.F.L.) = 100.0 m
3. Lowest Water level (L.W.L.) = 94.00 m
4. Span arrangement = 5 × 15 m c/c of bearing
5. Length of bridge = (15 + 0.55) × 5 = 77.75 m
6. Road way = 7.5 m
7. Wearing coat = 0.075 m
8. Material used Concrete M-20 in plugs M-40 in kerbs and crash barrier M-30 in rest and steel Fe- 500
9. Designed Loading = 2 Lane class A or single lane 70R
10. Formation Level = 106.25m
11. Outer dia of well = 6.0 m
12. Inner dia of well = 4.9 m
13. Silt factor = 1
14. Submerged unit weight of soil (γsub) = 10 kN/m^3
15. (S.B.C.) at bottom of well foundation = 490 kN/m^2
16. Soil properties below well cap,

(a) Cohesive force (C)= 0,

(b) Internal angle of fraction (ϕ) = 30°

17. Clear water way = 5 × 15 −2.0 × 2.0 − 2.0 × 1.2

= 68.6 m

18. Lacy's water way = 4.8√Q = 97.19m
19. Restriction=$100-\frac{68.6}{96}\times 100 = 28.54$ %
20. Discharge/meter =$\frac{410}{68.6}$=5.97 m^3/sec/m
21. Mean Scour depth(dsm)=$1.34\left(\frac{d_{sm}^{\,2}}{k_{sf}}\right)^{\frac{1}{3}} = 4.41$m
22. Scour depth below H.F.L.

(a) For pier = 2 × 4.41 =8.82 m

(b) For abutment = 1.27 × 4.41 = 5.60 m

23. Depth of the foundation = $8.82 + \frac{4.41}{5}$ =9.97 m

but we provide 15.0 m including cutting edge

24. Depth of well required below L.W.L./Top of well cap = 9.97-6= 3.70 m<10.00 m (proposed)
25. Mean scour level of pier well = 100.00 − 2 × 4.41 = 91.18 m say 92 m, Mean scour level of abutment well , 100.00− 1.27 × 4.41 = 94.39 m which lie within abutment well cap mean scour level kept same as pier well.

Design of Well Foundation

S.No.	Specification	Vertical Loads	L-Direction F.L. (kN)	L-Direction L.A. (m)	L-Direction M.L. (kNm)
1	D L Reaction of Super Structure	720		−0.50	−450
2	L L Reaction	590.0		−0.50	−295
3	Horizontal/Lateral Force		75.0	6.8 + 17.0 =23.80	1904
4	D L of sub structure	1548.0		−0.950	−1471
5	Earth Pressure				
	Back wall		667	6.48+17.0=23.48	16765
	Wing wall		119.0	6.48+17.0=23.49	2794
	Abutment wall		1837.87	2.9 + 17.0 = 19.9	39740.0
6	Weight of the well cap 3.14x(6x6x1.2x2.4)/4	678.24			
7	Weight of the steining with well curb $\frac{3.14(6^2-4.9^2)}{4}$x11x24	4145			
8	Weight of sand contained in well $\frac{3.14(6^2-4.9^2)}{4}$x9x18	2543.4			
9	Weight of water filled in well $\frac{3.14(6^2-4.9^2)}{4}$x8x10	1256			
10	Consider 100% Buoyancy on well $\frac{3.14(6^2)}{4}$x17x10	−4805			
11	Consider 100% Buoyancy on abutment 1.15 × 6.0 × 4.9× 10	−276			
12	**Total**	**6399.64**			
13	Moment due to 14.0 cm shifting and 1in 70 tilting			$0.14 + \frac{17}{80} = 0.3625.0 \times$ 4953	1795.0
			2698.87		**60481. 0**

Active Earth Pressure at the top of well cap = $P_{\alpha 1} = 0.3 \times (6.0 + 1.2 + 1.3) \times 18 = 45.9$ kN/m^2

Active Earth Pressure at the bottom of well = $P_{\alpha 1} = 45.9 + 0.3 \times 18 \times 1.0 = 51.3$ kN/m^2

Passive Earth Pressure at the base of well = $Pp = 5 \times 10.0 \times 12 = 600$ kN/m^2

Now taking the Moment (M) about the well base due to Active Earth Pressure

$$M = \frac{(45.9 + 51.3)}{2} \times 12.0 \times 4.0 \times \left[\frac{2 \times (45.9+51.3}{(45.9+51.3}\right] \times \frac{12}{3}$$

= 16905.0 kNm

Now taking the Moment (M) about the well base due to Passive Earth Pressure

$= \frac{600}{2.0} \times \frac{}{3.0} \times 12 \times 4 = 57600.0$ kNm

The resultant earth pressure at bottom of well =

$$60481.00 + 16905.00 - 57600.0 = 11949.0 \text{ kNm}$$

The grip length (D) = 12.0 m, Length = 0.9 D = 10.8 meter

$Iv = \frac{LD^3}{12} = 1556.0m^4$, $IB = \frac{\pi}{64} \times (6^4 - 4^4) = 51.025$

m^4,

$\alpha = \frac{\text{Dia meterofwell}}{\pi D} = 0.12$

Design of Steining

According to the IRC: 78-2014, the minimum steining thickness should be 0.5 meter.

S.No.	Specification	Vertical Loads	L-Direction		
			FL(kN)	L.A. (m)	ML (kNm)
1	D L Reaction of Super Structure	720		−0.46	−331.20
2	L L Reaction	589.9		−0.46	−271.35
3	Horizontal/Lateral Force		74.9	6.7 + 3.0 =9.7	726.53
4	D L of sub structure	1547.9		−0.96	−1486.0
5	Earth Pressure				
	Back wall		667	6.46+ 3.0 = 9.46	6309.82
	Wing wall		118.0	6.46 + 3.0 =9.46	1116.28
	Abutment wall		1837.87	2.76 + 3.0 = 5.76	10586.13
6	Weight of well cap	678.24			
7	**Total**	**3536.04**			
8	Moment due to 14.0 cm shifting and 1in 70 tilting			$0.14 + \frac{0.36}{80}$ = 0.144× 2803.0	403.64
9	Active earth pressure up to scour level $\frac{0.3 \times 18.0 \times 3.0 \times 3.0}{2} \times 5$		**121.5**	1.0	**122.0**
			2819.27		**17175.85**

Table 2 Forces and Moments at Scour Level

Well curb – The grade of concrete to make the well curb is M 25 concrete. The well curb should be properly reinforced. In the designing of well curb the amount of minimum reinforcement (72 kg/cu.m) should be taken.

Cutting edge – The well curb consist a cutting edge. It is made with the mild steel and reinforcement should e greater than 40 kg/m.

Bottom plug – To design the bottom plug, the minimum concrete grade of M15 is taken into The base plug of 1.0 m thickness shall be introduced from the top of the kerb at a depth of 300 mm. The thickness of the plug underneath is tested by $t^2 = 1.18r^2\frac{q}{fc} = 0.41\text{m} < 1$ m safe

The bearing pressure at the base is 293kN/m^2 considered, and the radius of well is of 2.0 meter and the flexural strength of concrete is taken as 8300 kN/m^2

III. STUDY AND DISCUSSION

The analysis of the well foundation and design of various components of well are being Performed. The designing aspects of all the well components are discussed in detail. The well foundation components such well cap, top plug, bottom plug and well curb are shown in the figure 1 and the Reinforcement in the outer and inner portion of the well is shown in figure 2

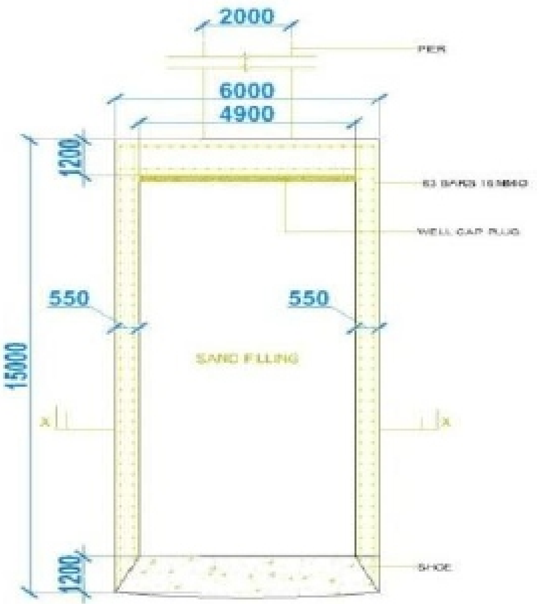

Figure 1 Typical Section of Well Foundation

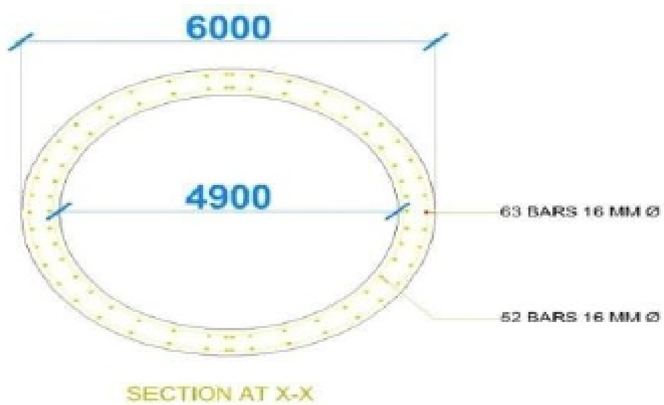

Figure 2 Detailing of Reinforcement

IV. CONCLUSION

- Well foundation is usually provided when the soil is sandy in nature. This type of bridge foundation is suitable where good soil is available at about 3 to 4 m below the bed level of the river.
- The Well foundation is mainly bearing based foundation which is suitable for alluvial region which is soft soil in nature. The well foundation is best suitable for small and medium size river because in case of alluvial region, the scouring action is playing important part in this case.

REFERENCE

[1] Srivastava Rajendra Kumar & Srivastava Manas "Minor Bridges and Culverts, Principles and Provisions"

[2] IRC: 05, Standard Specifications & Codes of Practices for Road Bridges, Section I (General features of Design) Indian Road Congress New Delhi India 2015

[3] IRC: 06, Standard Specifications & Codes of Practices for Road Bridges, Section II (Loads & stresses) Indian Road Congress New Delhi India 2017

[4] IRC: SP:13, Guide lines for Design of small Bridges & culverts Indian Road Congress New Delhi India 2008

[5] IRC: SP: 78, Standard Specifications & Codes of Practices for Road Bridges, Section VII (Foundations & sub Structure) Indian Road Congress New Delhi India 2014

[6] Varma Rakesh Srivastava Rajendra Kumar "Review of existing bridge system in small rivers in alluvial region of Uttar Pradesh" Published in International Journal of Technical Innovation in Modern Engineering and Science in 2019.

[7] Ritu Tomar(2010), "Study of Well Foundation under Different Grip Length and Loading Conditions." (Indian Geotechnical Conference – 2010)

[8] HarshaYadavet.al[1] (2011), Design of well foundation

[9] Amit Srivastava,(2012), Review of causes of foundation failures and their possible preventive and remedial measures

[10] Chowdhury, J. P. Singh et al,(2012), Seismic Response of Well Foundation with Dynamic Soil Structure Interaction

[11] Yash S. Gandhi (2016), "Comparative Study Of Pile Foundation Design For Bridge Pier With Working Stress Method And Limit State Method". (IJEDR)

[12] Devdarsan R(2017), An Analytical and Experimental Investigation of Varying Scour Depth in Well Foundation Including Dynamic Interactions

[13] Mohini Dhande and M.M. Chaudhari, (2017)- „Comparative Analysis and design for deck slab of minor bridge by effective method and finite element method".(ICRTEST) Vol. 5

[14] Thool Kushal P., Pawar Sachin L.,(2018), Design of Well Foundation

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Study of Sustainable Options of Superstructure of Navigational Bridges on Major Rivers

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A B S T R A C T

Inland waterways are one of the oldest mode of transportation between large cities which are build near rivers. These waterway are considered as a existing highways made by nature itself. Many countries recognizes this potential of inland waterways, that inland waterways important way of transportation and developed it for public as well as commercial purpose. Hence ,Government of Indian is also planning to develop inland waterways as they are most efficient , produces very low pollution , and requires very less amount of budget as compare to construction of highways or expressways , But one of major problem is that in development of these national waterways are the bridges which build on these waterways need to designed such that they allow crossing of cargo as well domestic ships underneath them. For that Indian Waterway Authority of Indian provided some guidelines for the vertical clearance between H.F.L and bottom of the bridge superstructure and horizontal clearances between two piers .In this study we considered that the stretch of NW1 from Prayagraj to Barhi.e build on river Ganga. In this stretch the average depth of river 2m according to EIA report for national waterways, may 2016. Hence as per IWAI regulation ,2006 section4 we provided 50 m span of truss bridge and 50 m span of pre- stressed box girder bridge and compare them on the basis of the cost of construction. From the study, it can be concluded that the Box girder bridges are more economical than truss Bridge and but it can be seen that the depth of the beam required is less in case of truss bridges, which leads to increase the vertical clearance of truss bridges.

Keywords - EIA, National Waterways, Box-Girder, Truss Bridge, IWAI Introduction

I. INTRODUCTION

Navigational spans are required to cross the river which are used for navigational purpose. These spans are need to designed as per the guidelines of IWAI. Generally, 40m to 50m spans are provided for navigational span especially in Uttar Pradesh. There are following types of superstructure provides such as-

i. Open web girder bridge
ii. Pre-stressed boxed girder bridge.
iii. Cantilever span bridge.

Generally, Open web girder and box girder bridges for spans upto 70m -80m ,because cantilever spans are costlier to construct for span lesser then 70m to 80m. Hence here we compare the open web bridge with PSC Box girder bridge on basis of cost .

II. METHODOLOGY

To commence with the PSC Box Girder was manually designed by using limit state method based on IS 456:2000, IS 1343:2012, IRC 112:2011, IRC18:2000. For designing of 50m box girder span the guideline are mentioned in IRC 112:2011,IRC1343:2012 and IRC18:2000, have been kept in mind while designing PSC Box -girder. For better understanding plan of the girder has also been made on AUTO CAD.

The Open Web Girder was also firstly designed based on IS 800:2007, IRC 112:2011, IRC 24:2010. For the design and analysis 50 m span all the guidelines as mentioned in IRC: 24-2010, IS:800-2007, have been kept in mind while designing girder. For better understanding plan of the girder has also been made on AUTO CAD.

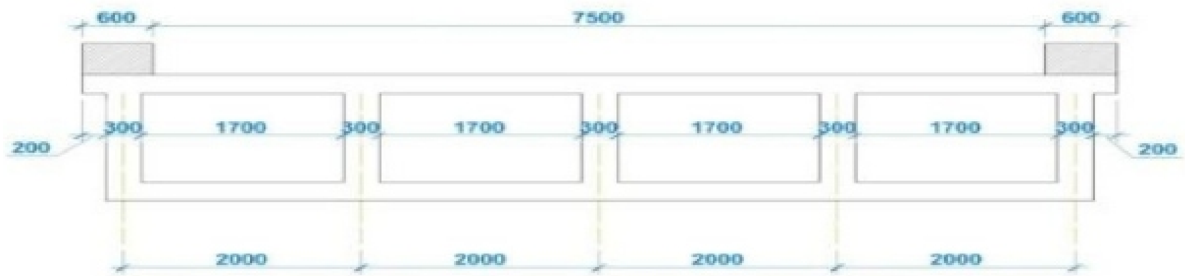
Both the Girders are of 50m and subjected to same type of loading i.e., 70R tracked vehicle load for 2 lane road .Hence after designing of both ,calculated the cost of construction both the spans.

2.1 Design of PSC- Box Girder

2.1.1 Design Data of Box Girder

1. Span = 50m.
2. Cross section = multi celled box girder
3. Cell dimensions = 2 wide 2.5 m deep
4. Road width = 7.5m
5. Wearing coat = 75mm
6. Thickness of web =300mm
7. Thickness of top and bottom slabs = 300mm
8. Grade of concrete = M60.
9. Loss ratio = 0.82
10. Grade of Reinforcement = Fe-415 HYSD bars.
11. Maximum permissible stresses in concrete and steel
    i. Permissible stress in concrete at stage of transfer (fct)=20N/mm^2
    ii. Permissible tensile stress (class 1 type structure) = ftt=ftw=0.
    iii. Yield strength of steel = fy = 415 N/mm^2

2.1.2 Preliminary Dimensions



CROSS SECTION OF DECK SLAB

2.1.1 Designing of Slab Pannel

- Maximum Bending Moment in shorter direction due to dead load = 3.086 kN-m.
- Maximum Bending Moment in shorter direction due to live load(i.e 70R tracked vehicle load) = 32.165 kN-m

- Maximum Shear force due to dead load = 7.871 kN
- Maximum Shear force due to live load = 56.052 kN
- The design moment and shear force are determined as per provisions provided in IRC :112-2011 are
  Mu= [1.35M
  D.L+1.5ML.L] =52.41 kN-m
  Vu =[1.35MD.L+1.5ML.L] =94.72 kN
- Effective depth of slab required = d

$$=\sqrt{\frac{Mu}{0.138\ .fck\ .b}} = \sqrt{\frac{52.41\times10^{6}}{0.138\ \times60\times1000}} = 79.60\ \text{mm}$$

- Overall Depth adopted (D) = 300 mm
- Adopt Effective depth ,d = 250mm

2.1.1 Design of Web Girder

Design moment and shear forces at service and ultimate load are represented in table 1

(a)Bending moments (outer web girder)					
Section	**Dead load B.M($M_{D.L}$)**	**Live load B.M (ML.L)**	**Service load B.M (MD.L+ML.L)**	**Ultimate load B.M (1.35 $M_{D.L}$ +1.5 $M_{L.L}$)**	**Unit**
At Middle of span	14928	5775	20703	28815	kN-m
(b)shear force (Inner Girder)					
Section	Dead load Shear force ($V_{D.L}$)	Live Load Shear force ($V_{L.L}$)	Service load Shear force (VD.L+ VL.L)	Ultimate load B.M ($1.35V_{D.L}$+ 1.5 $V_{L.L}$)	Unit
At support end of span	1194.25	367	1561.25	2162.74	kN

2.1.5 Pre-stressing force

For simply supported span of 50m ,cable profile is selected such that secondary moment generated becomes zero. Cable profile is selected as shown in figure.

$$P = \frac{A.f_{br}\ .Z_b}{Z_b + Ae}. = \frac{1.77\times10^{6}\times14.62\times1.29\times10^{9}}{1.29\times10^{9}+1.77\times710^{6}\times25} = 12972.640\ \text{kN}$$

By providing freyssinet system with anchorage 27K- 15 (27 srtant of 15.2 mm dia)
In 110 mm dia duct of cables
Forces in each cable = (27× 0.8 × 265) = 5724
Provide 4 cables carrying the intial prestressing force of P=4× 5000 = 20000 kN

Area of every srtand of 15.2mm diatemdon =140 mm^2
Total area of four cables = AP = 4× 3780 = 15120 mm^2

- Area of Tension Reinforcement required to resist the moment is calculated by the equation ,

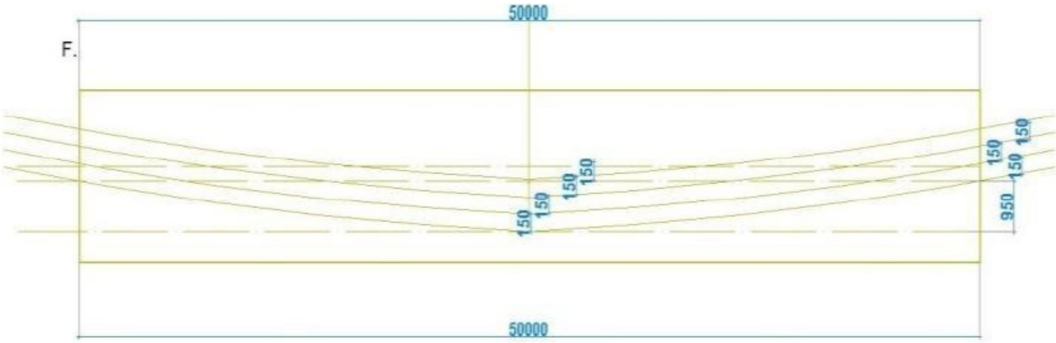
$$M_u = 0.87\ \times f_y\ \times A_{st}\ \times d \times (1 - \frac{A_{st}\times f}{b.d.f_{ck}})$$

$$52.41 \times 10^{6} = 0.87\ \times 415 \times A_{st}\ \times 250 \times (1 - \frac{A_{st}\times415}{1000\times250\times60})$$

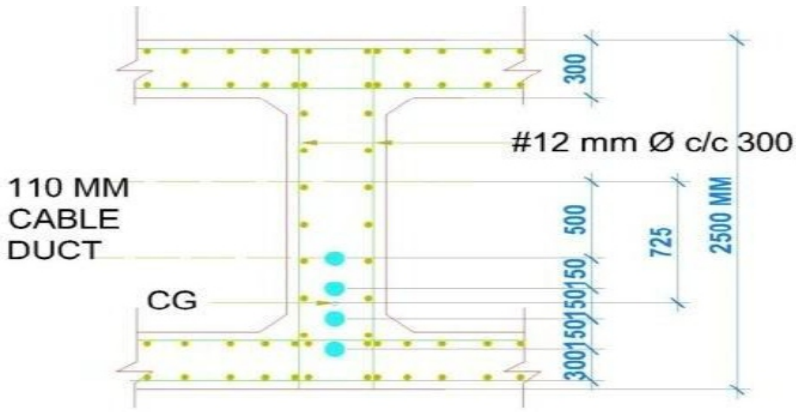
Solving, A_{st} =590 mm^2

Maximum Shear force due to dead load = 7.871 kN
Maximum Shear force due to live load = 56.052 kN
The design moment and shear force are determined as per provisions provided in IRC :112-2011 are
Mu= [1.35M
D.L+1.5ML.L] =52.41 kN-m
Vu =[1.35MD.L+1.5ML.L] =94.72 kN
Effective depth of slab required = d

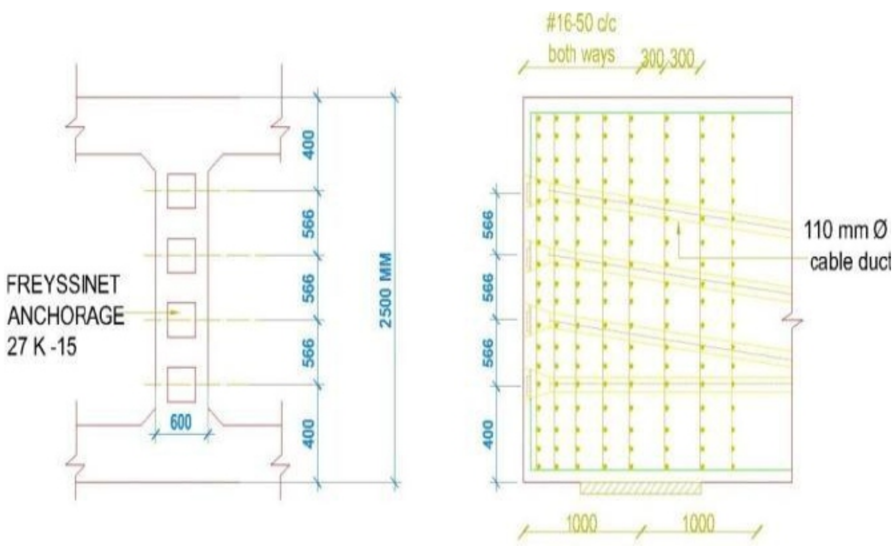
Area of 27 srtands in every cable =(27× 140) =3780 mm^2 Provide ,14 mm bars at 150 mm spacing center to center (i.eAst = 1056 mm^2) as main reinforcements and 12 mm diameter bars at 150mm centers as distribution reinforcements.



2.1.6 Details of longitudinal reinforcement to avoid shrinkage cracks reinforcement



2.1.7 Details of extra reinforcement in end bock zone



2.1.8 Estimate of Box Girder Bridge

The total cost of for the given cross section of box- girder is estimate as per Schedule rate of cpwd ,and it is approximately 90 lakhs rupee .

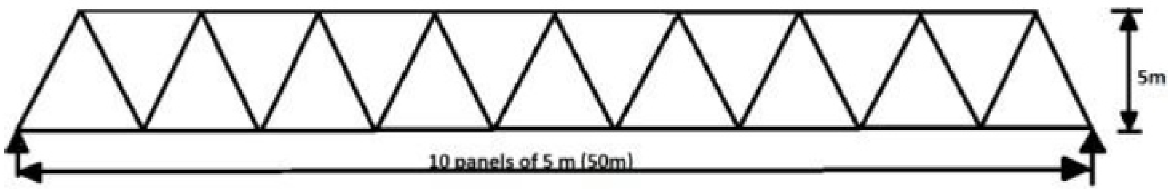
2.2. Open Web Girder

2.2.1 Design data :

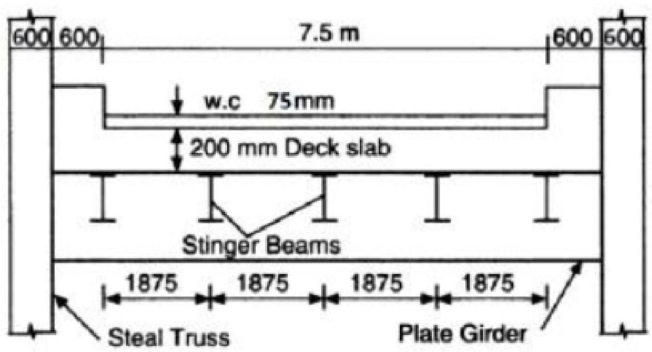
1.Effective span = 50 m.
2.Roadway = 7.5 m(two lanes).
3.Kerbs = 600 mm.
4. Loading : IRC 70R tracked vehicle.
5. Materials: M-25 Grade Concrete and Fe-415 HYSD bars for deck slab. Rolled steel sections with an yield stress of 236N/mm^2 confirming to IS:226 and IRC:24 are available for use.

2.2.2 Arrangement of Members

The configuration of the Warren truss and the arrangement of cross girders and stringers are shown in



(a) WARREN TRUSS



(b)CROSS SECTION OF DECK

2.2.3 Design of Slab Section

The total design ultimate load moments are Short span moment=MBu=[1.35 MDL +1.5MLL]=48.525 kN.m/m
Long span Ultimate moment MLu =6.22kN.m/m

$$\text{Effective depth of slab} = d = \sqrt{\frac{Mu}{0.138\, f_{ck}.b}} = 118.597 \text{ mm}$$

Adopt effective depth, d =200mm and overall depth of 250mm
Using 12mm diameter bars
Effective depth provided= 200mm

$\left(\frac{M_u}{b.d^2}\right) = \left(\frac{48.525 \times 10^6}{1000 \times 200^2}\right) = 1.213$, using M-25 grade concrete and Fe-415 HYSD bars

Read out the percentage of reinforcement required from Table 3 of SP:16 Design Aids

$$p_t = 0.36 = \frac{100 A_{st}}{bd}$$

therefore, $A_{st} = 720\text{mm}^2$
For short span , Provide 12 mm diameter bars at 120 mm centers (A_{st} provided = 942mm^2)

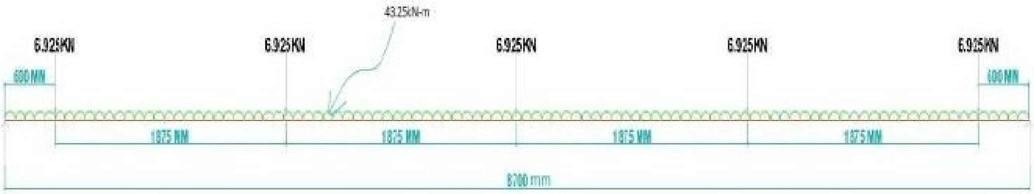
For long span , provide 10mm diameter bars at 150mm centers

2.2.4 Design of Stringer Beams

Maximum B.M. due to dead load = 50.29 kN-m
Maximum B.M. due to live load including impact factor =296.953 kN-m
Maximum shear force due to dead load =40.235 kN
Maximum S.F. due to live load including impact factor = 237.5625 kN
Design B.M. = (1.35×50.29+1.5× 296.953) = 513.30 kN-m
Design S.F=(1.35× 40.35+1.5× 1.25 × 190.05)= 410.82 kN
Section Modulus $Z = (M/\sigma_b) = (513.30\times 10^6/236) = 3.422\times 10^6 \text{mm}^3$
Use ISWB-600 ($Z= 3.54\times10^6\ \text{mm}^3$)
$\text{Shear}_2\ \text{stress}_2 = (410.82\times10^3)/(11.2\times600)$
=61.14N/mm < 85N/mm (Safe)

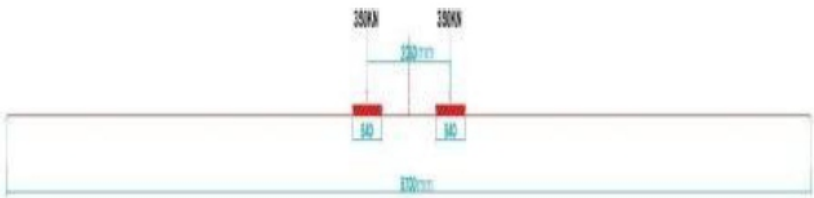
2.2.5 Design of Cross Girders:

The maximum dead load bending moments and shear force is computed as;



MDL = [(205.45 × 8.7 × 0.5) – 43.25 ×4.35×0.5 ×4.35) – (6.925×3.75)− (6.925×1.875)]
= 419.60 kN-m VDL= 205.45kN

The maximum live load bending moment including impact occurs when the two tracks are spaced symmetrically from the centre of cross girder.



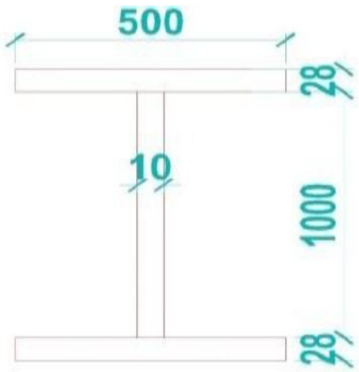
(a) POSITION OF LIVE LOAD FOR MAX. BENDING MOMENT

(b) POSITION OF LIVE LOAD FOR SHEAR FORCE

Maximum bending moment due to live load occur when the CG of load passes the center of span MLL $=1.4\,[(0.5\times350\times8.7)-(0.5\times350\times2.05)]$
$=1630$KN-m

Maximum shear force due to live loads occur when one of the edges of the track is 1.2m from the kerb. Maximum shear force including impact is computed as:
VLL$=1.4[(350\times6.475)/8.7+1.4[(350\times4.425)/8.7]$
$=613.8$kN

Total design B.M $=(419.58+1630)=2049.58$ kN-m
Total design S.F. $=(205.45+613.8)=819.25$ kN



2.2.6 Design of Steel Truss
A warren truss with 10 panels of 5m each is used Span of the truss = 50m
Height of Truss = (1/10)span = (50/10) =5m

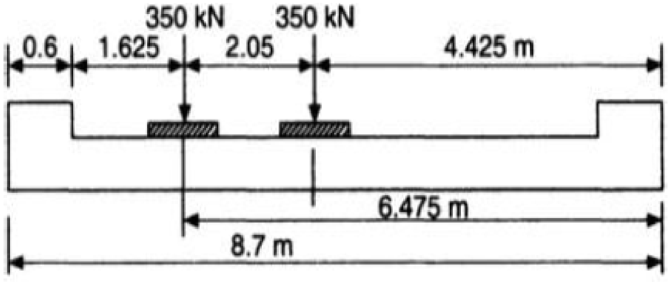
a. Dead loads due to deck slab , wearing coat, stringer beams and cross girders acting at each node = 205.45 kN≈206 kN

Self – weight of stress = $(0.15L+5.5)$
$=(0.15\times50+5.5)=13$ kN/m

Self – weight at each node point = $5\times13=65$ kN Total dead load = $(206+65)=271$ kN
Live loads : I.R.C. Class 70R loading

Maximum B.M. is produced when the class 70R vehicle is closet to main girder.

Maximum load transferred when one track is at 1.625m from the edge of the kerb as shown in figure



Load Position for Truss Design.

Maximum load transferred when one track is at 1.625 m from the edge if the kerb W = [(350 × 6.475)/8.7]+[350 ×4.425)/8.7] = 439 kN

Impact factor =10%

Live load including impact = (439 ×1.1) = 483kN

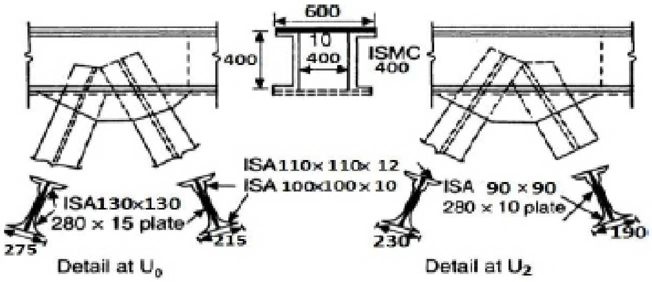
Therefore Average u.d.l = 483/4.57 = 105.68 kN/m

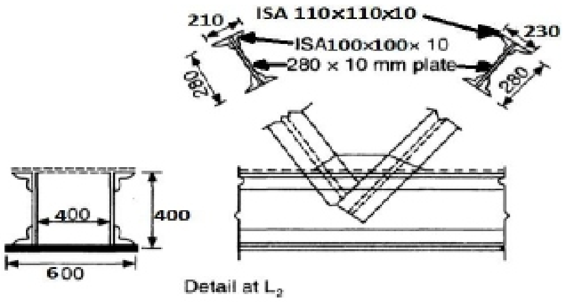
b. Forces in Truss Members

Influence lines are drawn for forces in the various members are calculated as shown in table 2

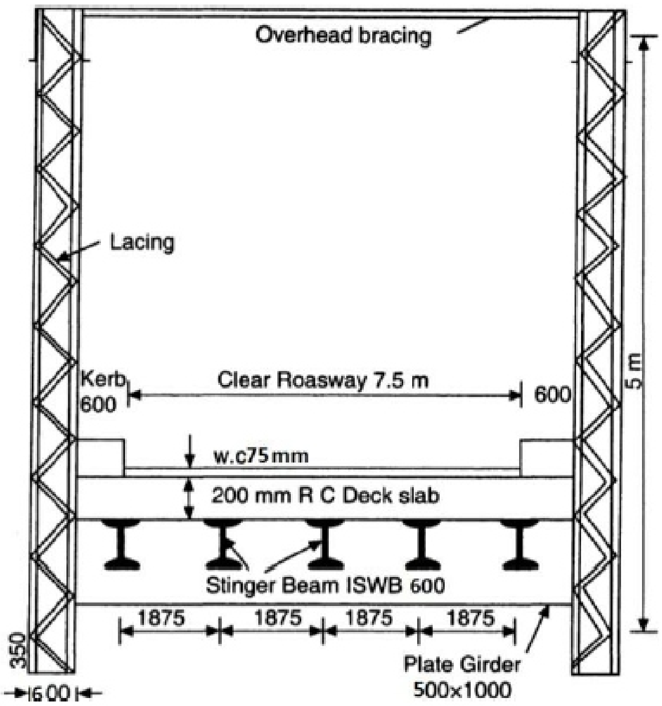
Member	Forces due to Dead loads (kN)		Forces due to live load (kN)		Combined loads (kN)		Design forces (in kN)
	Tensile	Compressive	Tensile	Compressive	Maximum	Minimum	
L_0L_1	610	-	219	-	−829	−610	−829
L_1L_2	1694	-	588	-	−2282	−1694	−2282
L_2L_3	2506	-	871	-	−3377	−2506	−3377
L_3L_4	3048	-	1058	-	−4106	−3048	−4106
L_4L_5	3320	-	1150	-	−4470	−3320	−4470
U_0U_1	-	1220	-	417	+1637	+1220	+1637
U_1U_2	-	2168	-	738	+2906	+2168	+2906
U_2U_3	-	2846	-	968	+3814	+2846	+3814
U_3U_4	-	3252	-	1106	+4358	+3252	+4358
U_4U_5	-	3388	-	1152	+4540	+3388	+4540
U_0L_0	-	1364	-	464	+1828	+1364	+1828
U_0L_1	1364	-	464	-	−1828	−1364	−1828
U_1L_1	-	1061	32	410	+1471	−32	+1471 −32
U_1L_2	1061	-	410	32	−1471	+32	−1471 +32
U_2L_2	-	758	86	356	+1114	−86	+1114 −86
U_2L_3	758	-	356	86	−1138	+86	−1114 +86
U_3L_3	-	454	140	302	+756	−140	+756 −140
U_3L_4	454	-	302	140	−756	+140	−756 +140
U_4L_4	-	152	194	248	+408	−198	+400 −194
U_4L_5	152	-	248	194	−400	+194	−400 +194

2.2.7. Members designed for the maximum axial force are such as show in figure





2.2.8 Cross- section of steel truss bridge



2.2.9 Cost of the construction of truss –bridge

The total cost of for the given cross section of open web girder is estimate as per Schedule rate of cpwd ,and it is approximately 140 lakhs rupee.

III. RESULT

a) Total depth of the box girder is 2.5 m.
b) Total depth of open web girder bridge is 1m .
c) Cost of construction of 50m box girder bridge of 8.7m width is 90 lakhs .
d) Cost of the construction of 50 m open web girder bridge of width 8.7 m is 140 lakhs .

IV. CONCLUSION

a) Depth of open web girder bridge is very less as compare to the box girder ,therefore the can be used where very good vertical clearance required
b) PSC- Box girder require almost 35% less amount then open web girder bridges for span of 50m.

but this percentage is goes on decreasing as we increase the required span length .

REFERENCE

[1] IRC: 18.(2000). Design criteria for prestressed concrete road bridges (post tensioned concrete), IRC, New Delhi, India.

[2] IRC: 6. (2010). Loads and stresses, IRC, New Delhi, India.

[3] IRC:112. (2011). Code of practice for concrete bridges, IRC, New Delhi, India.

[4] IS1343.(1980). Indian Standard code of practice for prestressed concrete (First Revision), BIS, New Delhi, India

[5] N. Krishna Raju,. (1995). Prestressed Concrete, Tata McGraw- Hill Publishing company Limited, New Delhi.

[6] N. Krishna Raju,. (2015), Design of bridges, oxford & IBH publishing Co.Pvt.Ltd., New Delhi.

[7] S. Maleki (2002). "Effect of deck and support stiffness on seismic response of slab girder bridges", Engineering Structures, 24, 219-226.

[8] Vikash Khatri, Pramod Kumar Singh and P.R.Maiti (2012)."Comparative study of prestressed steel concrete composite bridge of different span length and girder spacing", International Journal of Modern Engineering Research, 2(5), 3917-3922.

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Cost Comparative Study of the Circular Elevated Storage Reservoir and Intze Elevated Storage Reservoir with Varying H/D Ratio and Large Capacities

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A B S T R A C T

In India more than 34% of its total population lives in urban area. Domestic water is major problem in this area, So as to solve this problem innovative design and solutions to existing problem is essential hence for that study of Elevated Storage Reservoir (ESR) is undertaking. It is a time-consuming task to design and cost estimation of overhead water which has needs lot of expertise.Water is very important commodity in today's life. In urban areas, elevated water tank play key role in distribution system. There is various type of water such as Rectangular tank, circular tank, Intze tank, shape of tank play important role in cost of the structure elevated storage reservoir. Various researchers have performed analysis on elevated storage reservoir with changing h/d ratio. In this paper, cost of the water intze tank and circular tank is being calculated for various small capacities and varying h/d ratio. In this paper material cost is considered cost study that is cost of concrete and cost of steel. Ms excel sheet. Cost comparative study for large capacity of water tank (400,500) cubic meter both elevated circular tank and intze tank of varying h/d ratio and super structure, sub structure to be discussed below in details. At the result of large capacity (500 cubic meters) elevated Intze water tank is more economical as compared elevated circular water tank is being used for design of circular storage reservoir tank and intze storage reservoir. As the result for 400 cubic meters of elevated water tank when h/d ratio 0.5 is more economical but other h/d ratio (0.75, 1, and 1.25) is elevated circular water tank is more economical compared as elevated water tank.

Keywords - Elevated Water Tanks, Design, Cost Effectiveness, Limit State, Microsoft Excel Design Spreadsheet etc

I. INTRODUCTION

Presently days, water is most fundamental needs to spare as conceivable on the grounds that as population expands the interest of waters are increments. Also, as we probably are aware Water is a significant component of a day to day existence. The need of water is for drinking, water system, mechanical assembling, fire suppression, and so on so it is important to manage the capacity of water as appropriately as could be expected under the circumstances. Water tank is the holder for putting away water in huge amount. The water tanks are developed to store water at a ground level for the day by day use, treatment of water, item producing, emergency storage rainwater storage Tanks, etc. The water tank is a significant structure for the structural building for the human culture. The improvement of the human development is presented a wide range of sorts of water storage tank. Water tanks are utilized to store water. Cost, shape, size and building materials utilized for developing water tanks are affected by the capacity of water tank. Shape of the water tank is a significant structure boundary since nature and power of stresses depend on the Shape of the water tank. In general, for a given capacity, circular shape is preferred because stresses are uniform and lower compared to other shapes lesser stresses imply, lower amounts of material required for development which cuts down the development cost of water tanks. The order of water tank is as demonstrated as follows

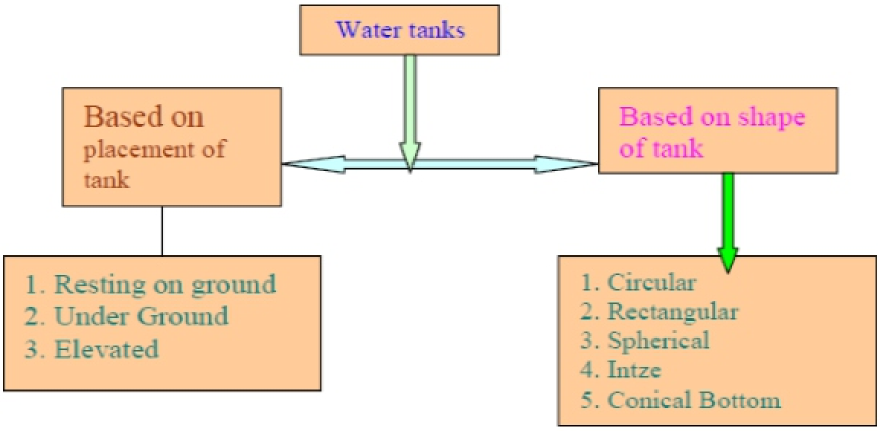

FIGURE 1: Water Tank Classification

II. DIMENSIONAL PARAMETER

The term "dimensional parameter" refers to the relative ratios between dimensions of a given form that fix its Shape. The parameters and shapes of tanks vary according to their shapes and capacity. As far as the framed Supporting structures are concerned; the vertical distance between two levels of horizontal braces is 3m.

III. THEORETICAL FORMULATION

In this study, water tank is analyzed using continuity analysis method because it is assumed that joints are monolithic therefore one need to construct the various components of water tank simultaneously for ensuring monolithicness.

The present work employs continuity analysis for studying various combinations of depth & accordingly Diameter of circular water tank, for finding an optimum geometry for elevated circular water tank with flat top and bottom for known capacity.

IV. OBJECTIVES

- To make a study about the design of water tanks.
- To do cost comparison amongst the Circular and Intze elevated water tank.
- To make a study about the guidelines for the design of liquid retaining structure according to IS code.
- To know about the design Philosophy for the safe and economical design of water tanks.
- To study the various forces acting on a water tank. Understanding the most important factors that play role in designing of water tanks.
- Preparing a water tanks design which is economical and safe, providing proper steel reinforcement in concrete and studying

V. METHODOLOGY

Microsoft Excel Spreadsheet Design Program- MESDePro: The generation of MESDePro- a versatile and adaptable design tool for elevated rectangular and circular reinforced concrete water tanks was prompted by the rigorous and lengthy manual design of reinforced concrete water tanks.

The program considers loop (or ring) design for the circular tank. Moreover, the input values in the white-background cells are the only values to be adjusted to suit the desired requirements. A familiarization study of the program would be very helpful, coupled with the basic understanding of liquid retaining concrete structures design principles- to have a better grasp of the embedded formula in the program.

The choice of elemental design is made in the program instead of the whole-frame design modeling approach for design simplicity.

VI. PARAMETRIC STUDY

In the present parametric work, continuity analysis method is used to analyze the tank and cost comparison is done to Optimize with various combination of H/D ratio of the tank.

The range of variable parameters is as mentioned below:

1. Tank Capacity 400,500 cubic meter for circular tank and intze tank.
2. Height of container tank varies from H/D ratios.
3. Depending upon the capacity. The variation in cost of tank for different H/D ratio is shown

VII. RESULT AND DISCUSSION

In this research paper design was done of circular elevated storage reservoir, intze elevated storage reservoir and comparative study of both storage reservoir large capacity with varying h/d ratio per cubic meter also caparisoned between super structure and sub structure per meter cube.

(a). Hence all large capacity (400,500 cum) with varying h/d ratio per cubic meter has shown in figure (1), (2),(3).

H/D ratio		0.50 ratio	0.75 ratio	1.00 ratio	1.25 ratio
Elevated Circular Water Storage Reservoir	Total Cost	1314378.01	1210370.19	1187559	1185117.62
	Cost Per Cubic Meter	3285.945025	3025.925475	2968.8975	2962.79405
Elevated Intze Water Storage Reservoir	Total Cost	1291758.54	1224178.85	1214608.7	1227839.03
	Cost Per Cubic Meter	3229.39695	3060.4477125	3036.52175	3069.597575

TABLE.1 400 m^3 Capacity with varying h/d ratio per cubic meter

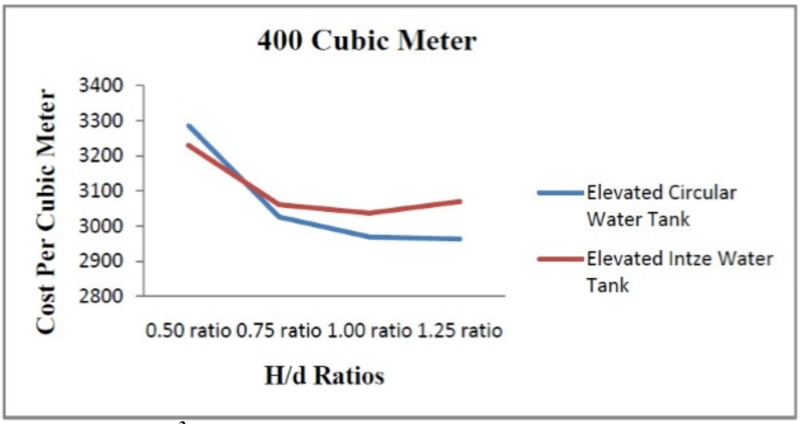

Figure.1400 m^3 Capacity with varying h/d ratio per cubic meter

From Table1 Cost estimated 400 cubic meter capacity for both water storage reservoirs to different h/d ratios (0.50, 0.75, 1.00, and 1.25) and figure.1 graphical data represented.

- In circular elevated storage reservoir h/d ratio is 0.5 of cost per cubic meter of elevated tank Rs 3285.945025. And h/d ratio is 1 of cost per cubic meter of elevated tank R.s. 2968.8975 I.e. means when h/d ratio increases up to 1 then cost per cubic meter of tank decreases. When the h/d ratio is 1.25 on cost per cubic meter of elevated tank Rs. 2962.79405. we have seen that cost per cubic meter of elevated tank increases when h/d ratio>1
- In elevated intze water storage reservoir (E.S.R) h/d ratio is 0.5 of cost per cubic meter of elevated tank Rs. 3229.39695. And h/d ratio is 1 cost per cubic meter of elevated tank Rs. 3036.52175. i.e. means when h/d ratio increases (<1) then cost per cubic meter of elevated tank decreases. When the h/d ratio is 1.25 on cost per cubic meter of elevated intze tank Rs. 3069.597575.we have seen that the cost per cubic meter of elevated tank increases when h/d >1.

H/D Ratios		0.50 ratio	0.75 ratio	1.00 ratio	1.25 ratio
	Total Cost	1748138.3	1610680.3	1563974.6	1571204.4
Elevated Circular Water Storage Reservoir	Cost Per Cubic Meter	3496.2765	3221.3606	3127..9492	3142.4089
Elevated Intze Water Storage Reservoir	Total Cost Per Cubic Meter	1593139.5	1517634.6	1505706.1	1512299.8
	Cost per Cubic Meter	3186.279	3035.2692	3011.422	3024.5995

TABLE.2 500 m^3 Capacity with varying h/d ratio per cubic meter

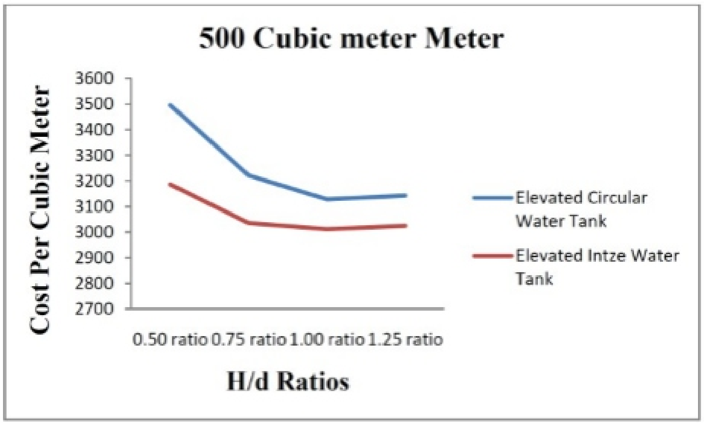

Figure 2. 500 m^3 Capacity with varying h/d ratio per cubic meter

From Table.2 Cost estimated 500 cubic meter capacity for both water storage reservoirs to different h/d ratios (0.50, 0.75, 1.00, and 1.25) and figure.2 graphical data represented.

- In circular elevated storage reservoir h/d ratio is 0.5 of cost per cubic meter of elevated tank Rs. 3496.2765. And h/d ratio is 1 of cost per cubic meter of elevated tank R.s 127.9492. I.e. means when h/d ratio increases up to 1 then cost per cubic meter of tank decreases. When the h/d ratio is 1.25 on cost per cubic meter of elevated tank Rs. 3142.40886. we have seen that cost per cubic meter of elevated tank increases when h/d ratio>1
- In elevated intze water storage reservoir (E.S.R) h/d ratio is 0.5 of cost per cubic meter of elevated tank Rs. 3186.27896. And h/d ratio is 1 cost per cubic meter of elevated tank Rs.3011.422. i.e. means when h/d ratio increases (<1) then cost per cubic meter of elevated tank decreases. When the h/d ratio is 1.25 on cost per cubic meter of elevated intze tank Rs. 3024.5995.we have seen that the cost per cubic meter of elevated tank increases when h/d >1.

(B).Cost comparison between super and sub structure (Column and Bracing) of Elevated circular water storage reservoir and Elevated intze water storage reservoir.

H/D Ratios		0.50 ratio	0.75 ratio	1.00 ratio	1.25 ratio
Elevated Circular Water Tank Of Super Structure	Total Cost	785970.7086	724271.2265	719955.785	741919.547
	Cost Per Cubic Meter	1964.926772	1810.678066	1799.889463	1854.798868
Elevated Intze Water Tank Of Super Structure	Total Cost	812330.7058	766598.1262	764722.84	782899.274
	Cost Per Cubic Meter	2030.826765	1916.495316	1911.8071	1957.248185

Table.3 400 m^3 capacity with varying h/d ratio per cubic metr of super structure

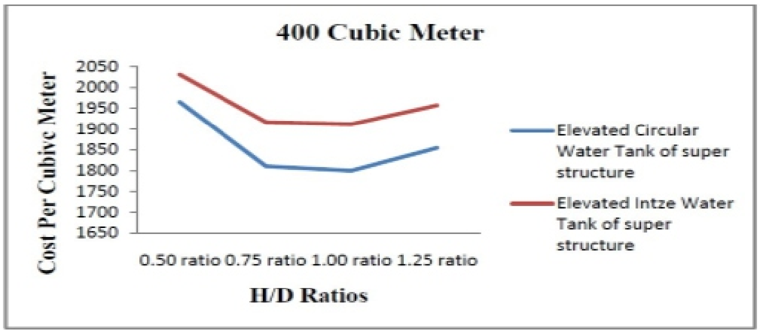

Figure 3. 400 m^3 capacities with varying h/d ratio of super structure

From Table.3 Cost estimated 400 cubic meter capacity for both water storage reservoirs at different h/d ratios (0.50, 0.75, 1.00, and 1.25) of superstructure and figure.3 graphical data represented.

- In elevated circular water storage (E.S.R.) of super structure h/d ratio is 0.5 of cost per cubic meter of elevated tank Rs.1964.926772. And when h/d ratio is 1 of cost per cubic meter of elevated tank R.s. 1799.889463 i.e. means when h/d ratio increases up to 1 then cost per cubic of tank decreases. When the h/d ratio is 1.25 on cost per cubic meter of elevated tank Rs.1854.798868.We have seen that cost per cubic meter of elevated tank Increases when h/d ratio>1.
- In elevated intze water storage reservoir (E.S.R) of super structure when h/d ratio is 0.5 of cost per cubic meter of elevated tank Rs. 2030.826765. And when h/d ratio is 1 cost per cubic meter of elevated tank Rs.1911.8071. i.e. means when h/d ratio increases (<1) then cost per cubic meter of elevated tank decreases. On the h/d ratio is 1.25 on cost per cubic meter of elevated intze tank Rs. 1957.248185. We have seen that the cost per cubic meter of elevated tank increases when h/d ratio>1.

H/D Ratios		0.50 ratio	0.75 ratio	1.00 ratio	1.25 ratio
Elevated Circular Water Tank Of Super Structure	Total Cost	1017620.898	935316.3734	927004.548	952427.472
	Cost Per Cubic Meter	2035.241796	1870.632747	1854.00909	1904.854944
Elevated Intze Water Tank Of Super Structure	Total Cost	997551.593	946756.1666	943547.567	964985.739
	Cost Per Cubic Meter	1995.103186	1893.51233	1887.095134	1929.971478

Table.4 500 m^3 capacity with varying h/d ratio per cubic meter of super structure

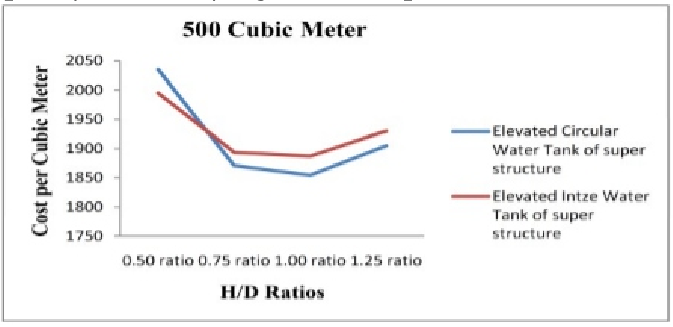

Figure 4.500 m^3 capacities with varying h/d ratio per cubic meter of super structure

From Table.4 Cost estimated 500 cubic meter capacity for both water storage reservoirs at different h/d ratios (0.50, 0.75, 1.00, and 1.25) of superstructure and figure.4 graphical data represented.

- In elevated circular water storage (E.S.R.) of super structure h/d ratio is 0.5 of cost per cubic meter of elevated tank Rs.2035.241796. And when h/d ratio is 1 of cost per cubic meter of elevated tank R.s.1854.00909. i.e. means when h/d ratio increases up to 1 then cost per cubic of tank decreases. When the h/d ratio is 1.25 on cost per cubic meter of elevated tank Rs.1904.854944.We have seen that cost per cubic meter of elevated tank Increases when h/d ratio>1.
- In elevated intze water storage reservoir (E.S.R) of super structure when h/d ratio is 0.5 of cost per cubic meter of elevated tank Rs. 1995.103186. And when h/d ratio is 1 cost per cubic meter of elevated tank Rs.1887.095134. i.e. means when h/d ratio increases (<1) then cost per cubic meter of elevated tank decreases. On the h/d ratio is 1.25 on cost per cubic meter of elevated intze tank Rs. 1929.971478. We have seen that the cost per cubic meter of elevated tank increases when h/d ratio>1.

H/D Ratios		0.50 ratio	0.75 ratio	1.00 ratio	1.25 ratio
Elevated Circular Water Tank Of Sub Structure	Total Cost	528407.3054	486098.9667	467603.227	443198.07
	Cost Per Cubic Meter	1321.018264	1215.247417	1169.008068	1107.995175
Elevated Intze Water Tank Of Sub Structure	Total Cost	479427.8306	457580.7196	449885.816	444939.755
	Cost Per Cubic Meter	1198.569577	1143.951799	1124.71454	1112.349388

Table.5 400 m^3 capacity with varying h/d ratio per cubic meter of sub structure

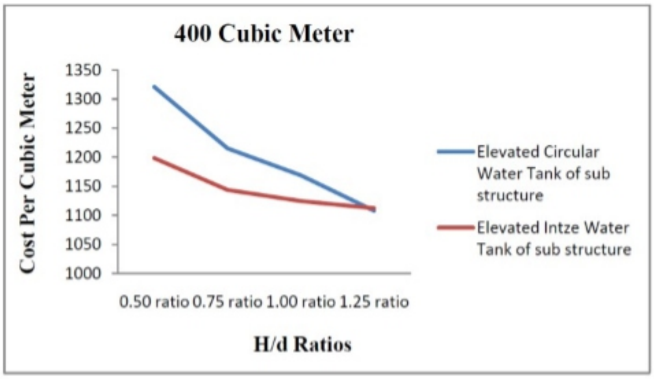

Figure 5.400 m^3capacity with varying h/d ratio of sub structure

From Table.5 Cost estimated 400 cubic meter capacity for both water storage reservoirs at different h/d ratios (0.50, 0.75, 1.00, and 1.25) of substructure (Column & bracing) and figure.5 graphical data represented.

- In elevated circular water storage (E.S.R.) of substructure h/d ratio is 0.5 of cost per cubic meter of elevated tank Rs.1321.018264.And when h/d ratio is 1 of cost per cubic meter of elevated tank Rs. 1169.008068. I.e. means when h/d ratio increases up to 1 then cost per cubic of tank decreases. When the h/d ratio is 1.25 on cost per cubic meter of elevated tank Rs.1107.995175.i.e have seen that cost per cubic meter of elevated tank decreases when h/d ratio>1.
- In elevated intze water storage reservoir (E.S.R) of substructure when h/d ratio is 0.5 of cost per cubic meter of elevated tank Rs. 1198.569577.And when h/d ratio is 1 cost per cubic meter of elevated tank Rs. 1124.71454.i.e. means when h/d ratio increases up to 1 then cost per cubic of tank decrease. When the h/d ratio is 1.25 on cost per cubic meter of elevated intze tank Rs. 1112.349388 .We have seen that the cost per cubic meter of elevated tank decreases when h/d ratio>1.

H/D Ratios		0.50 ratio	0.75 ratio	1.00 ratio	1.25 ratio
Elevated Circular Water Tank Of Sub Structure	Total Cost	730517.3543	675363.9299	636970.068	618776.954
	Cost Per Cubic Meter	1461.034709	1350.72786	1273.940136	1237.553908
Elevated Intze Water Tank Of Sub Structure	Total Cost	595587.8863	570878.4112	562158.55	547314.009
	Cost Per Cubic Meter	1191.175773	1141.756822	1121.3171	1094.628018

Table.6. 500 m^3 capacity with varying h/d ratio per cubic meter of sub structure

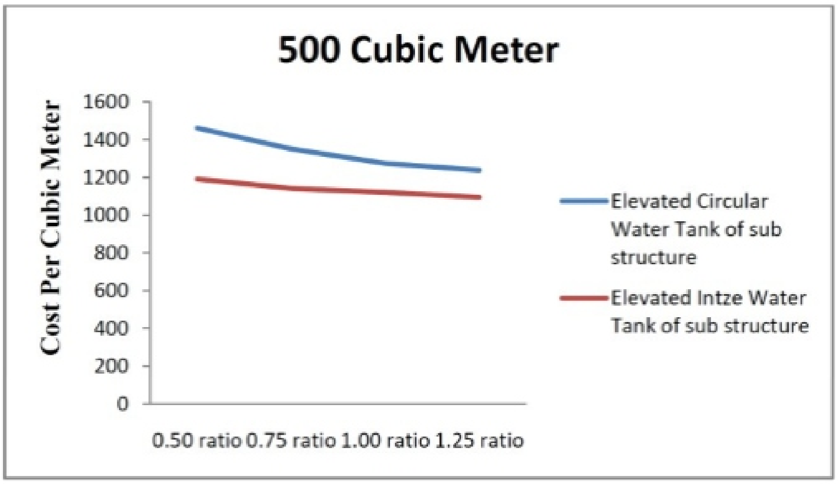

Figure 6.500 m^3 capacity with varying h/d ratio of sub structure.

From Table.6 Cost estimated 500 cubic meter capacity for both water storage reservoirs at different h/d ratios (0.50, 0.75, 1.00, and 1.25) of substructure (Column & bracing) and figure.5 graphical data represented.

- In elevated circular water storage (E.S.R.) of substructure h/d ratio is 0.5 of cost per cubic meter of elevated tank Rs. 1461.034709.And when h/d ratio is 1 of cost per cubic meter of elevated tank Rs.1273.940136.I.e. means when h/d ratio increases up to 1 then cost per cubic of tank decreases. When the h/d ratio is 1.25 on cost per cubic meter of elevated tank Rs.1237.553908.i.e have seen that cost per cubic meter of elevated tank decreases when h/d ratio>1.
- In elevated intze water storage reservoir (E.S.R) of substructure when h/d ratio is 0.5 of cost per cubic meter of elevated tank Rs. 1191.175773. And when h/d ratio is 1 cost per cubic meter of elevated tank Rs. 1121.3171 .i.e. means when h/d ratio increases up to 1 then cost per cubic of tank decrease. When the h/d ratio is 1.25 on cost per cubic meter of elevated intze tank Rs. 1094.62801.We have seen that the cost per cubic meter of elevated tank decreases when h/d ratio>1.

VIII. CONCLUSION

In this research was done design and cost estimate for comparative study of Elevated circular storage reservoir and Elevated intze storage reservoir for small capacity 400,500cubic meter in two parametric studies.

(a) All large capacity (400,500) cubic meter and varying h/d ratio (0.50, 0.75, 1.00, 1.25) per cubic meter

1. From the result it can be observed that for 400 m^3 capacity of tank, as h/d ratio increases the cost of both circular and intze tank for all value of h/d ratio. The cost of elevated intze tank is less than elevated circular tank at 0.5 h/d ratios and other h/d ratio an elevated circular water tank is economical

2. From the result it can be observed that for 500 m^3 capacity tank, as h/d ratio increases the cost of both circular and intze tank for all value of h/d ratio. The cost of elevated intze tank is less than elevated circular tank at all h/d ratios.

(B) Comparison between Elevated circular storage reservoir and an elevated intze storage reservoir of super structure and substructure to estimate cost for economical.

1. 400,500 m^3 Capacity for both Elevated reservoir storage reservoirs of super structure when h/d ratio increases up to h/d ratio 1 the per cubic meter cost decreases. When h/d ratio is 1.25 then the cost of per cubic meter in increases as shown in the figure 3, 4. Hence elevated water tank of 400 m^3 is economical only h/d ratio 0.5 and the other h/d ratio (0.75, 1, and 1.25) are more economical is an elevated circular water tank. For 500 m^3 intze water tank more economical as compared an elevated circular water tank.
2. 400,500 m^3 Capacity for both Elevated circular storage reservoir and Elevated intze storage reservoir of sub structure (Columns, Bracings) is shown in table 5,6 costs per cubic meter. When h/d ratio increases cost per cubic meter decrease in all the h/d ratio (0.50, 0.75, 1.00, 1.25)

REFERENCE

[1] Patel H, Pitroda J, Parikh KB (2014). "Analysis of intze elevated water tanks". Civil Eng Dep SNPIT RC,

[2] Halkude SA, Jadhav AB. (2014) "Optimization of Circular Elevated Service Reservoir". Int J Eng Res Technol.

[3] Altinkaya Ş, Yalçin S.(2020)" Some applications of generalized srivastava-attiya operator to the bi-concave functions". Vol. 21, Miskolc Mathematical Notes.

[4] Indhudhar CM, Shivananda DKP, Dattatreya DJK.(2016)" Cost Optimization of Elevated INTZE Water Tank". Bonfring Int J Man Mach Interface.(Special Issue)

[5] Soni NK.(2018)" Cost Analysis of Overhead Tank Foundation with Varying Depth of Soil above Footing". Int J Res Appl Sci Eng Technol.6(3):2435–9.

[6] Analysis and Design of Rcc Overhead Water Tank for Seismic and Wind. 2018;

[7] Chandana T, Surendhar S V. (2019)"Comparative seismic and cost analysis of RCC circular, rectangular and intze elevated water tank". Int J Innov Technol Explor Eng.

[8] NJS. (2015)"Design Analysis & Comparsion of Intze Type Water Tank for Different Wind Speed and Seismic Zones As Per Indian Codes". Int J Res Eng Technol.

[9] Kapadia I, Patel P, Dholiya N, Patel N. (2017)"Analysis and Design of INTZE Type Overhead Water Tank under the Hydrostatic Pressure as Per IS : 3370 & IS : 456 -2000 by Using STAAD Pro Software". Int Res J Eng Technol.

[10] Rajkumar, Mangalgi S.(2017)" Response Spectrum Analysis of Elevated Circular and Intze Water Tank". Int Res J Eng Technol.

[11] Secab IET, Karnataka V. (2018)"Response spectrum analysis of elevated water tank".

[12] Mhamunkar S, Satkar M, Pulaskar D, Khairnar N, Sharan R, Shaikh R(2019)" Design and Analysis of Overhead Water Tank at Phule Nagar, Ambernath". Int Res J Eng Technol [Internet]

[13] Kamara ME.(2010)" Design of circular concrete tanks". Struct Congr 2010.

[14] Adilakshmi B, Suribabu P, Ramesh R. (2018)"Design , Analysis and Optimization of Intze Type Water Tank for Different Parameters As Per Indian Codes" .

[15] Oyesile WB.(2012)" Comparative Study on the Design of Elevated Rectangular and Circular Concrete Water Tanks".

[16] Sanghvi N. (2019)"Optimum design of Reinforced Concrete Intze Type Water Tank using Genetic Algorithms". SSRN Electron J.

[17] Ruchi P. Barve PSB.(2015)' Effect of Variation of Diameter to Height (D/H) Ratio on the Cost of Intze Tank Using IS 3370:1965 and IS 3370:2009". Int J Innov Res Sci Eng Technol.

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Piled Raft Foundation as the Sustainable Option for High Rise Buildings

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A B S T R A C T

This paper presents the designing of piled raft foundation for 20 storeys high rise building which is done manually and building modelling is done using standard software STAAD Pro and results on AutoCAD. The design carried out is according to IS 13920:1993 , IS 456: 2000, IS 2950-1-1998 and IS 2911-1-1 : 2010. Nowadays, we furnish a deep foundation as shallow foundation which is not found to be effectual in dispensing adequate safety and dependability. The piled raft foundation is an amalgamation of pile foundation and shallow raft foundation which has gained popularity in recent years. Also, advancement in the load bearing capability of a shallow foundation utilizing the load that is shared betwixt raft and piles which obtains an efficient and economized design.The load imposed by the superstructure is more than requisite bearing capability and piles provided are inadequate to cater the load imposed alone. Pile foundation is provided with a pile cap or raft slab forming piled raft foundation. Notwithstanding, the common method of designing neglects the bearing contribution from raft to soil causing a conservative estimation of the foundation performance. It was found that raft will take the load first and piles will take the balance. It was discovered that when the pressure is more, dispersion area is less, then these types of foundations are preferable as full capacity of raft is utilised, while pile bears the balance.

Keywords - Piled Raft Foundation, High Rise Building, Raft, Pile, Vertical Loads, Simple Design Method.

I. INTRODUCTION

Presently, the inhabitants, the industrial and technical revolution are increasing at an alarming rate as time is passing. In the construction field, the architects and engineershighly emphasize on the vertical development i.e. the high rise and super high rise buildings construction. Amongst several important factors, that are considered, the lateral load is the important one in order to increase the heights of the buildings. Thereafter, the structural designer designs the certain types of buildings that have higher durability over the whole span of time. Just recently, there encountered an advancement in the knowledge, employing piles have lessened the settlement in the raft and the total settlements would effectuate superabundant thrift, economizing the safety and workability of the substructure. Suchlike foundation uses the piles below the raft. This is designated as a piled raft foundation.

This report is an upgrade on the study of design of piled raft, along with the problems associated to the designs. Different analysis methods and piled raft foundations designs are furthermore assessed, and their abilities with constraints are examined. Thereafter , certain systematic mechanism are put into use to attenuate the complications in order to permit the functioning of foundation to be found. Finally, some designing aspects of piled rafts are reviewed. Withal, wherein a standard raft foundation doesn't lend to sufficient bolster, that can be strengthened by the accession of piles, which is together acknowledged as a piled raft foundation. This foundation, mostly used for high-rise edifice, in circumstances where the soil isn't feasible for averting the exorbitant settlement. They're growingly favoured volition for high-rise edifice. Ordinarily, piles contribute particularly to the inflexibility whereas raft contributes supplemental load bearing capacity. The intermixture of deep and shallow foundation is used where shallow foundation is not sufficient to take the load then deep foundations are added to enhance its load bearing capacity.

II. OBJECTIVE OF THE STUDY

This research represents the study of piled raft foundation for high-rise edifice in alluvial region, on the basis of analysis following have been said:

- to control the foundation settlement as well as pressure and
- to attenuate the specified raft thickness to succeed in the foremost economic foundation design.

III. DESCRIPTION OF THE RAFT AS WELL AS PILE:

S.no.	Structural Part	Dimensions
1	Building type	Residential building
2	No. of stories	G+19
3	Location	Lucknow
4	Seismic zone	III
5	Soil type	Alluvial Soil
6	Area	24×24 m
7	Soil Bearing Capacity	150kN/m^2
8	Type of structure	RCC space frame structure
9	Floor to floor height	3 m
10	External wall thickness	225 mm
11	Internal wall thickness	115 mm
12	Slab thickness	150 mm
13	Column size	600×600 mm
14	Connecting beam size	1000 ×1000 mm
15	Thickness of raft	500 mm
16	Upward pressure	6.81 t/m^2 on each side
17	Diameter of pile	500 mm
18	Pile length	10 m
19	Total load carried by pile group	4732 ton
20	No. of piles	225
21	Pile spacing	1.5m

Table 1 Geometrical Properties

IV. STRUCTURAL MODELLING

The floor plan of a regular edifice is displayed in figure below:

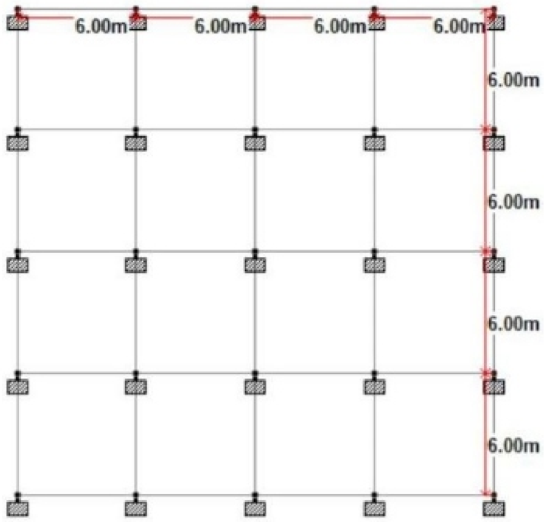

Figure 2: Floor plan of a building

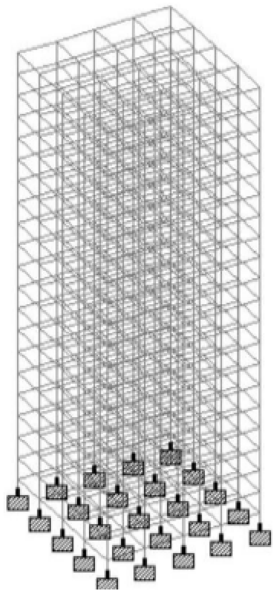

Figure 3: 3D view of the building

V. DESIGN OF FOUNDATION

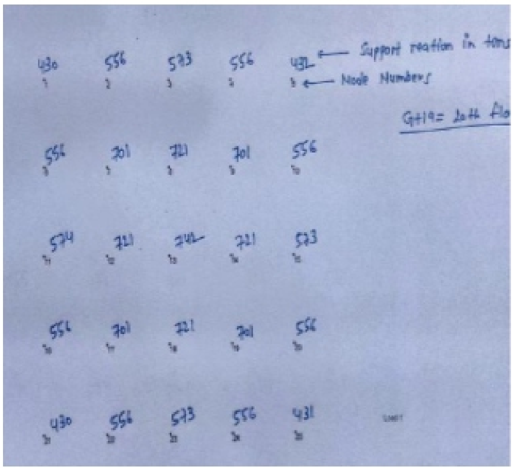

Figure 4: Support reactions in Ton

Calculation of load

Total load = 14894 ton

Area = 24 m×24 m & providing 1m wide apron for raft.

$$\text{Pressure on foundation } (q_c) = \frac{14894}{26 \times 26} = 22\ t/m^2$$

Which is more than safe bearing capacity 15 t/m² on 1.8 m below N.G.L. Hence, not safe.

$$\text{Area of footing, } B^2 = \frac{14894 \times 1.1}{15} = 1092.226\ m^2$$

$$B = \sqrt{1092.226} = 33\ m$$

In case, estimated footing area is not available so we have to restrict our footing to 26 m × 26 m which is only available. Therefore only option is to provide pile below raft.

Net balance area for which pile have to be provided, 22-15 = 7 t/m²

Total pile capacity = 7×26×26 = 4732 ton.

Design of Raft

For design of foundation ,

Net upward pressure

= 6.81 t/m2 treated as uniform upward pressure in each direction for design of components like raft slab and connecting beams of size 1000 × 1000 mm.

The thickness of raft is assumed 500 mm and effective span = 5.4 m

Max. factored moment at support = 249.0 kN. m Max. factored moment at mid span

= 124.5 kN. m~125 kN. m

Max. factored shear force = 28.0 kN

Design of raft slab

$$\text{Calculation of depth}(d) = \sqrt{\frac{M_u}{0.133 \times f_{ck} \times b}}$$

$$= 274\ mm < 500 - 75 - \frac{20}{2}$$

$$= 415\ mm\ O.K.$$

Area of steel (A_{st}) at support can be calculated as 1486 mm² Spacing of 16 mm bars c/c = 134 mm say 100 mm

Area of steel at mid span = 717 mm²

Spacing of 16 mm bars c/c

= 279 mm say 200 mm

Checking of Shear

$$r_v = \frac{V_u}{b.d} = 0.067\ N/mm^2$$

Percentage steel (p) = 0.024

Corresponding premissible shear stress (r_c)

$$= 0.29\ N/mm^2 > 0.067\ N/mm^2$$

Need not required checking in development length as slab is fixed with beam.

Design of beam

Load from slab = 40.86 t/m² = 408.6kN/m^2

Factored bending moment at support (M_u)

$$= 1226.0\ kN.m$$

Factored bending moment at mid span (M_u)

$$= 613\ kN.m$$

Factored shear force = 1839 kN

$$\text{Calculation of depth}(d) = \sqrt{\frac{M_u}{0.133 \times f_{ck} \times b}}$$

$$= 744\ mm < 1000 - 75 - \frac{20}{2}$$

$$= 915\ mm\ O.K.$$

Area of steel (A_{st}) at support is 3408 mm²

Nos. of 20 mm bars c/c = 9.99 nos. say 10 nos.

Area of steel at mid span =1635 mm²

Nos. of 20 mm bars c/c = 5.2 nos. say 5 nos.

Checking for shear

$$\text{Nominal shear stress } (\tau_v) = \frac{V_u}{b.d} = 2\ N/mm^2$$

Percentage of steel intension zone (p)

= 0.34, Corresponding

permissible shear stress as per table 19 of IS code

$$= 456 - 2000\ (\tau_c)$$

$$= 0.49\ N/mm^2$$

Hence, failed therefore shear reinforcement is to be provided in shape of vertical stirrups

Spacing of 4 legged stirrups c/c spacing

$$= \frac{0.87\ f_y A_{sv}\ d}{V_u - \tau_c\ b.d}$$

= 89mm say 90 mm due to ductile considerations No need of checking for bond stress and development length as being fixed beam.

Checking of punching shear

The maximum axel load on the column (P) = 7420 kN

The size of the column = 600 × 600 mm

Effective depth of the pedestal/beam = 915 mm

$$\text{Permissible two way shear}(\tau_c) = 0.25\sqrt{f_{ck}} \times K_s$$

$$= 1.25\ N/mm^2$$

where K_s
$= 0.5 + \beta_c$ & β is ratio of short to long side i. e. $0.5 + \frac{600}{600} = 1.5 > 1.0$,

so the value of K_s is taken as 1.0

Punching shear $= [(b + {}^{d}/_{2}) \times 2 + b \times 2] \times d$
$= 30332255\ mm^2$
Punching stress= $1.12\ N/mm^2$ i.e. $1.12 < 1.25\ N/mm^2$

O.K.

Design of pile foundation

Designing pile foundation for additional load bearing capacity of 7 t/m^2

Assuming an RCC pile of 10 m, overall length is driven into a deep stratum of alluvial soil having an unconfined compressive strength of 7 t/m^2.

Take pile dia as 500 mm and FOS is 2.5.

Given data: qu =7 t/m^2

$$C = \frac{qu}{2} = \frac{7}{2} = 3.5\ {}^{t}/_{m2}$$
d= 500 mm = 0.50 m
L = 10 m
FOS = 2.5

By the static formula, Using IS 2911 [Part 1, Section 1]

Ultimate load capacity for an individual pile, $Q_u = (Q_f + Q_b) = (q_f \times A_f + q_b \times A_b)$

For clay

Where, Adhesion factor for soft clay, $\alpha = 0.9$ Bearing capacity factor, Nc = 9

$q_b = C.N_c = 9 \times 3.5 = 31.5\ t/m^2$
$q_f = \alpha.C = 0.9 \times 3.5 = 3.15\ t/m^2$
Area of base, $A_b = (\pi/4) \times d^2 = (\pi/4) \times 0.5^2 = 0.196\ m^2$
Area of pile shaft, $A_f = \pi dL = 3.14 \times 0.5 \times 10 = 15.71\ m^2$
We get, $Q_u = 55.66$ ton
Calculating safe load for pile, $Q_s = \frac{Qu}{FOS} = 22.26\ ton$
For total load carried by the pile, Q_{ug} = Area $\times\ q_u$ = 4732 ton
Total no. of piles $= \frac{\text{Total load}}{Qs} = 212.5 \approx 225$ piles
Pile spacing, S = 3D = 1.5m
Pile arrangement in rectangular array i.e. 15×15.

For sand Bearing capacity factor, $N_q = 30$ (value depends on ϕ) $\phi = 30^{\circ}$

Point bearing resistance, $q_{pu} = \sigma. N_q$
Effective overburden pressure at the tip of the pile, $\sigma = \gamma.15D = 18\times15\times0.5$
$\sigma = 81\ kN/m^2 = 8.1\ t/m^2$
Area at base, $A_b = (\pi/4) \times d^2 = (\pi/4)\times0.5^2 = 0.196\ m^2$
$q_{pu} = 81\times30 = 2430$ kN = 243 ton
Ultimate point load, $Q_{pu} = q_{pu} . A_b$
$Q_{pu} = 476$ kN = 47.6 ton
Ultimate skin friction resistance, $Q_f = f_s . A_b$
Frictional resistance, $f_s = K. \sigma_{avg} . \tan\delta$
K = 2 for medium sand & $\delta = \frac{3}{4}\phi = \frac{3}{4}\times 30^o = 22.5^o$
$Q_f = f_{s1} . A_{s1} + f_{s2}. A_{s2}$
Where, A_s= Surface area of pile in contact with soil
$Q_f = 1581$ kN = 158.1 ton
Ultimate capacity, $Q_u = Q_{pu} + Q_f$
$Q_u = 2057$ kN = 205.7 ton

Safe load, $Q_s = \frac{Qu}{FOS} = \frac{2057}{2.5} = 822.8\ kN = 82.28\ ton$

Total load = 7×26×26 = 4732 ton.

VI. RESULTS AND DISCUSSIONS

This chapter, shows results and discussions about all considered parameters regarding design of piled raft foundation.

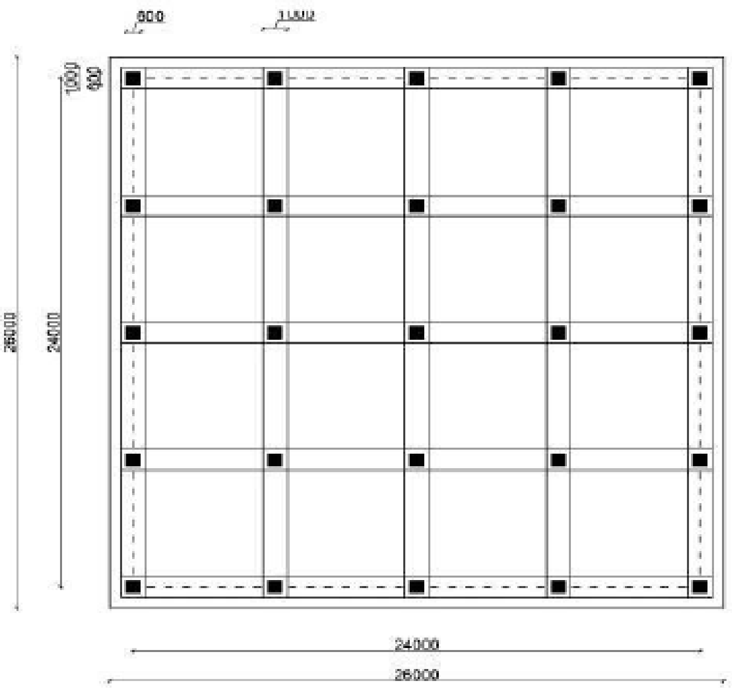

Figure 5: Raft Plan(all dimensions are in mm)

From the above figure, we can see that the area of plan is 24m×24m and further we have provided 1m apron which makes it 26m×26m.

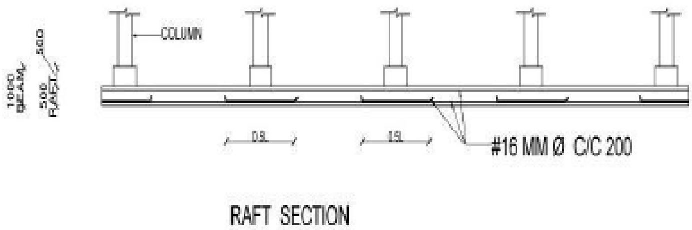

Figure 6: Raft Section (all dimensions are in mm)

Here, above figure shows the sectional view of raft representing beam of size 1000mm×1000mm, thickness of raft 500mm and column.

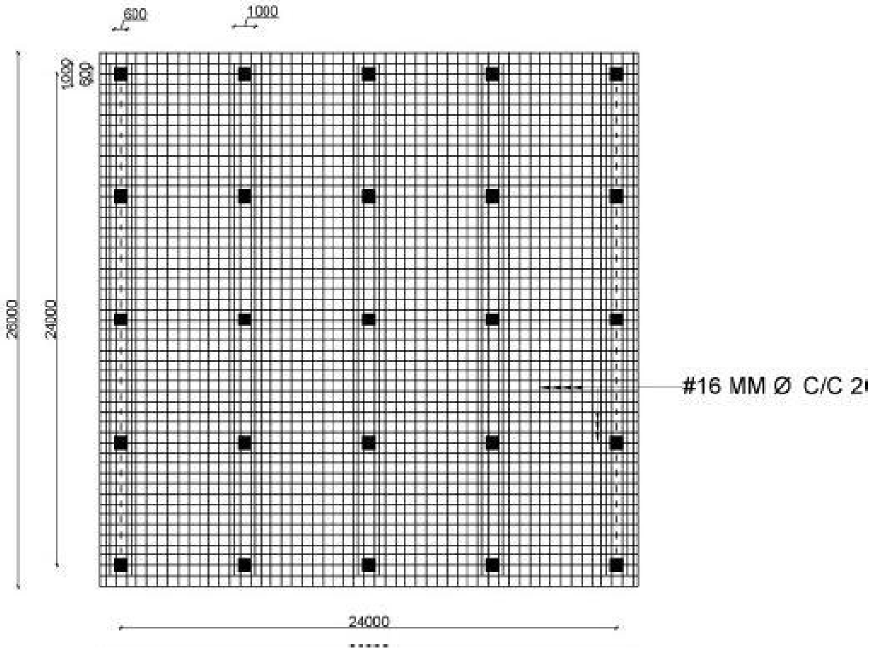

Figure 7: Raft top slab reinforcement (all dimensions are in mm)

From the above, we can see the top reinforcement of the raft provided having 200 bars of girth 16mm centre to centre and columns of size 600mm×600mm is considered for the foundation.

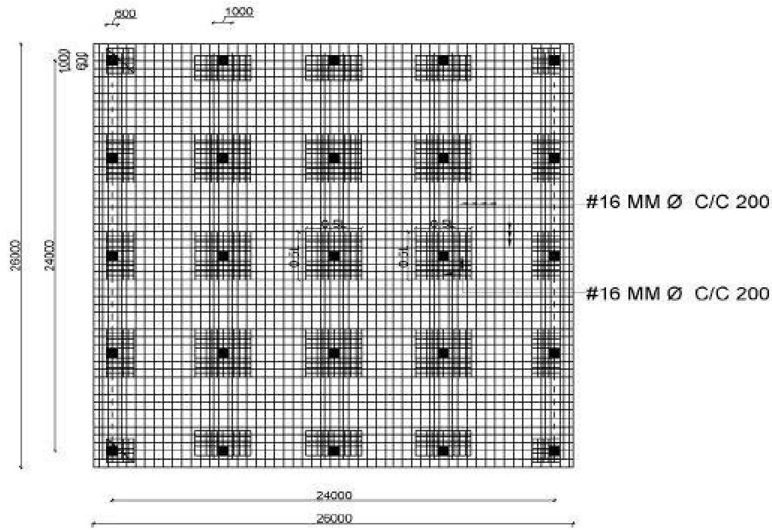

Figure 8:Raft bottom slab reinforcement (all dimensions are in mm)

From the above, we can see the bottom reinforcement of the raft provided having 200 bars of girth 16mm spacing centre to centre with a distance of 0.5L, considered for the foundation.

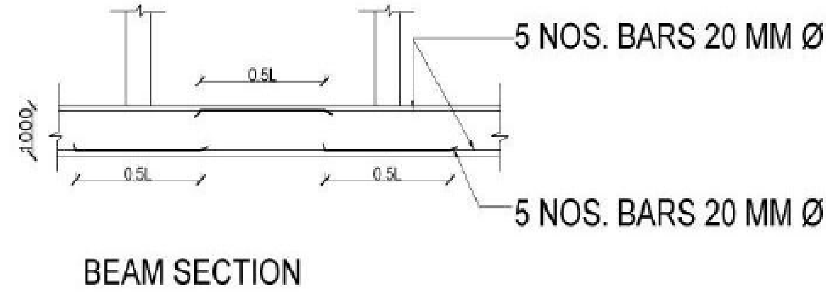

Figure 9: Beam Section for Raft (all dimensions are in mm)

Here, beam section of raft is shown that has reinforcement of 5 bars of 20 mm girth spacing centre to centre at a distance of 0.5L.

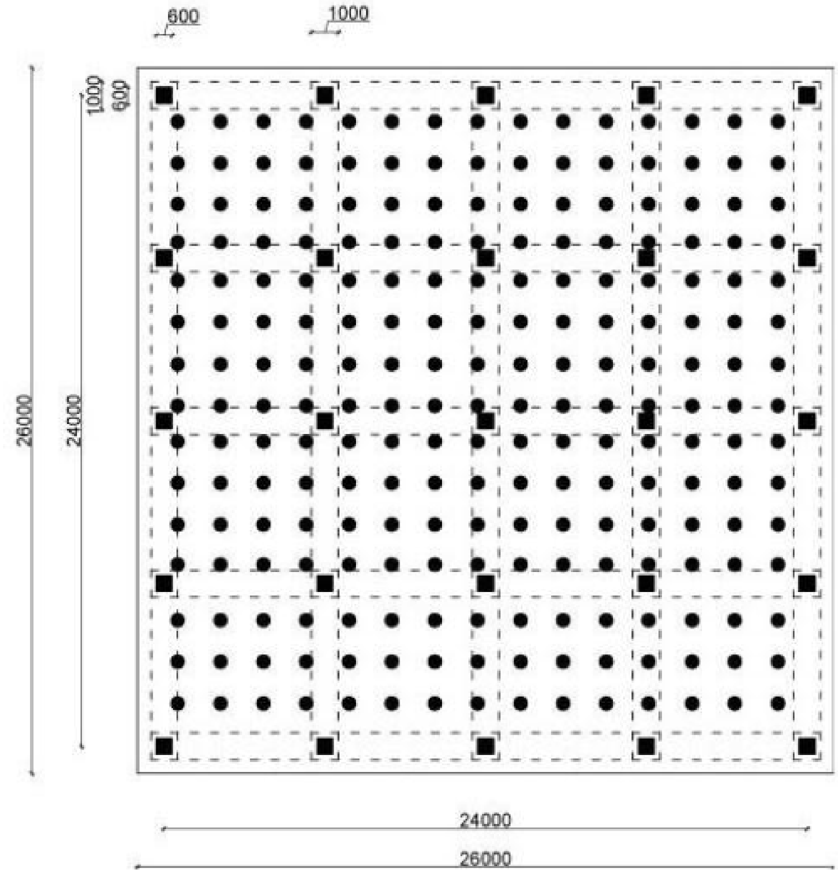

Figure 10: Piled Raft Design Plan (all dimensions are in mm)

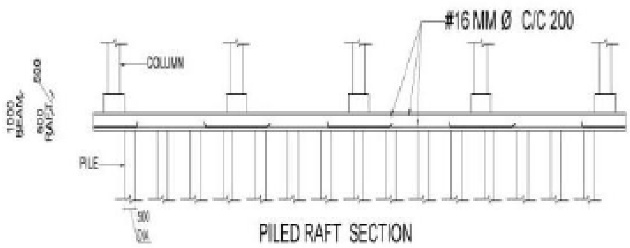

Figure 11: Piled Raft Section (all dimensions are in mm)

VII. DISCUSSION

- The places where the spread area is limited for accommodating the load pressure we have an option to cater balance load by providing piled raft.
- If we have area to spread upto required design area, it will become costlier as cantilever portion is more i.e. 33-24 = 9m means about 4.5m cantilever portion which will cost more.

VIII. CONCLUSION

The thesis targeted to investigate the distribution of imposed load under PRF for high rise buildings considering its effects and other factors.

This study summarizes, the main conclusions and recommendations drawn through the designing of piled raft foundation. So I conclude that:

1. it is cost effective as it reduces the number of pile and length of pile as well as thickness of raft.
2. when pressure is more, dispersion area is less than these types of foundations are preferable as full capacity of raft is utilised while balance is bear by piles. In this case we have assumed that raft will take the load first and pile will take the balance.

From above all I can say, piled raft foundation is much better than all other foundations for high rise buildings.

FUTURE SCOPE

To enhance the results obtained from the study, the following recommendations need to be considered:

- It is uncertain that which (raft or pile) will take the load first and get the optimised condition.
- Thus, further work may be suggested that assume first pile will take the load and balance will bear by raft. In this way a real study can be conducted regarding this type of foundation.

REFERENCE

[1] Harry G. Poulos, " Some aspects of the design of piled raft foundations" (1999)

[2] H.G. Poulos, "Piled raft foundations: design and applications" (2001)

[3] S.P.Bajad, R. B. Sahu, "An Experimental Investigation on Interference of Piled Rafts in Soft Soil" (2012)

[4] Ambarish Ghosh and B. Rituparna Dey, "Study On The Behaviour Of Pile-Raft Foundation In Cohesive Soil (2016)

[5] Sungjune Lee and Joon-Shik Moon, "Effect of Interactions between piled Raft elements and Soil on behaviour of piled foundation"(2016)

[6] D. Thoidingjam and K. R. Devi, " Behavior of Pile Raft Foundation in Organic Clay" (2017)

[7] Ruping Luo, Min Yang, and Weichao Li, "Analysis of Load Distribution Characteristics in Piled Raft Foundation" (2018)

[8] Phung Duc Long ,"Settlement analysis for piled raft foundations"(2018)

[9] Meisam Rabiei and AsskarJanalizadehChoobbasti, "Economic design optimization of piled raft foundations" (2018)

[10] Stefano Staculand Nunziante Squeglia, "Analysis of Laterally Loaded Piled Raft Foundation"(2019)

[11] Shweta Mishra, "Comparison Between Pile And Combined Piled Raft Foundation"(2019)

[12] IS 2950 (Part 1): 1981, Code of Practices for Design and Construction of Raft Foundation (Second Revision), Bureau of Indian Standards, New Delhi.

[13] IS 2911-1-1: 2010, Code of Practices for Design and Construction of Pile Foundation (Second Revision), Bureau of Indian Standards, New Delhi.

[14] IS 456:2000, Code of Practices for Plain Reinforced Concrete (Fourth Revision), Bureau of Indian Standards, New Delhi.

[15] Varghese P.C., Advanced Reinforced Concrete Design, Prentice Hall of India, New Delhi, 2001.

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