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Redefining Construction in India: Advancements in Prefabrication and Their Impact on the Industry

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Abstract - *This research paper examines the advancement of prefabricated (prefab) construction in India by conducting a literature study and a case study. The study aims to understand the different prefab construction techniques currently adapted in India and their uses from various perspectives, including time, cost, quality, and sustainability. The research methodology includes a comprehensive review of relevant literature and a case study of a prefab construction project in India. The case study provides an in-depth understanding of the challenges and opportunities for prefab construction in India. The findings suggest that prefab construction can significantly reduce construction time and cost while maintaining quality and sustainability. However, its adoption requires changes in the mindset and approach of stakeholders. The study concludes by proposing recommendations for the successful implementation of prefab construction in India, including standardization of processes and materials and incentivizing the adoption of prefab construction. Overall, this research provides valuable insights into the potential of prefab construction for sustainable and efficient construction practices in India*

1.INTRODUCTION

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Prefabricated construction systems, also known as modular construction, have gained significant attention in the Indian construction industry in recent years. Prefabrication involves manufacturing building components or modules in a controlled factory environment, which are then transported to the construction site and assembled. This method of construction is becoming increasingly popular in India due to its ability to offer several benefits, including faster construction time, improved quality control, and reduced labor costs. In India, prefabrication has a long history, with evidence of the use of precast elements in ancient Indian temples dating back to the 7th century. However, the modern prefabricated construction industry in India has its roots in the post-independence era when the government started promoting the use of prefabrication to address the housing shortage crisis. The use of prefabricated construction in India has evolved over time, with new technologies, materials, and design methods being introduced. Today, prefabrication is used in a variety of sectors, including affordable housing, commercial buildings, and infrastructure projects such as bridges and tunnels. The Indian government has also taken initiatives to promote the use of prefabricated construction, including launching the

2. IDENTIFY RESEARCH QUESTIONS AND COLLECTION OF DATA

To achieve our research objectives and scope, we have followed a systematic methodology that involves several steps Firstly, we formulated our research questions, objectives, and scope of the study, which helped us to understand the research area's limitations and the research questions we needed to answer.

- What are the different methods and advancements in prefabricated construction, and how can they enhance the benefits of this technique in the Indian construction industry?
- What are the significant obstacles that impede the progress of prefabricated construction in India, and how can they be addressed?
- What are the critical factors that affect the quality of prefabricated construction, and how are they interrelated?
- How does prefabricated construction impact the Indian construction industry, and what are its future prospects?

- How can planning systems evolve to support construction without hindering fundamental planning codes and space requirements.

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3. METHODOLOGY

Literature Study: Conduct a thorough review of existing research papers, books, and other relevant literature to understand the different methods, advancements, and obstacles in prefabricated construction.

- Identify case studies of various building systems to distinguish between prefabricated construction methods and conventional techniques.
- Analyze the construction process, both on-site and off-site, and evaluate the most widely used prefabricated systems, components, materials, and their joints available in India.
- Classify prefabricated components and compare them to conventional components to identify their advantages and disadvantages.
- Study the impact of prefabricated construction on the Indian construction industry and its future prospects.

Simulation:

- Formulate a matrix for different cases based on the collected data.
- Create a simulation using the matrix to compare the benefits and drawbacks of prefabricated construction with conventional techniques.
- Analyze the simulation results to identify the most effective techniques and advancements in prefabricated construction that can be used in the Indian construction industry.
- Evaluate the limitations of the study and suggest future research directions.

4. NEED OF PREFABRICATED CONSTRUCTION

Prefabrication construction has become a popular approach in the building industry as it offers several advantages over traditional construction methods. One of the main benefits of prefabrication construction is that it can significantly reduce the cost of construction. This is because the manufacturing of the building components can be done in a factory setting, which allows for better cost control, reduced waste, and increased efficiency. Moreover, the on-site construction time is reduced, which results in lower labor costs and reduced material waste.

Another advantage of prefabrication construction is that it can decrease the workload of construction. The manufacturing of building components in a factory setting reduces the need for on- site labor, which can help to mitigate the labor shortage that the construction industry is currently facing. This also results in a safer construction environment, as fewer workers are needed on- site.

The use of prefabricated components can also improve the strength and reliability of building designs. The manufacturing of components under controlled conditions in a factory setting ensures consistency in quality and precision, which can reduce the likelihood of errors and defects in the construction process. Moreover, prefabrication construction allows for the use of standardized components that can enhance the overall quality of the structure.

Prefabrication construction can also enhance the exhibition of the building. The use of prefabricated components can result in a more appealing and aesthetically pleasing finish. This is because prefabricated components can be manufactured with various finishes and textures, which can enhance the appearance of the

structure. Additionally, the use of prefabricated components can result in a more efficient use of space, as the components can be designed to fit specific dimensions and requirements.

5. WHY INDIA NEED TO SUCCEED IN PREFABRICATION TECHNOLOGY

India's housing crisis is a major challenge that needs to be urgently addressed to improve the lives of millions of people who currently lack access to affordable and quality housing. The shortage of housing in India, particularly in urban areas, has led to the proliferation of slums, which lack basic services such as potable water, sanitation, and solid waste disposal, among others. The lack of affordable housing is also closely linked to increasing urban poverty and destitution among economically weaker sections of society.

To address the issue of affordable housing, India needs to embrace prefabrication technology, which has the potential to improve the speed, efficiency, and affordability of housing construction. This technology involves the manufacturing of pre-designed building components in a factory, which are then assembled on-site, reducing construction time and labor costs. The use of prefabrication technology can lead to the production of higher quality and more affordable housing, making it a game-changer for India's housing sector.

Additionally, India needs to focus on developing sustainable habitats that maintain ecological balance. This involves adopting a symbiotic approach to rural and urban development while developing urban extensions of existing towns. This approach can mitigate the adverse impacts of urbanization on the environment and create livable and sustainable urban environments. The promotion of sustainable habitat development can be done through the use of green technologies, including renewable energy sources, water harvesting systems, and green roofs. Moreover, India's growing economy requires modern and efficient commercial spaces to support businesses and create employment opportunities.

Sustainable building practices can be adopted in commercial construction to reduce the environmental impact and operational costs of these buildings. This approach can contribute to India's efforts to mitigate the effects of climate change and improve the overall quality of life in urban areas. It can also promote economic growth by attracting businesses and investors who prioritize environmental and social responsibility. In conclusion, addressing India's housing crisis and promoting inclusive and sustainable urban development requires a multi-pronged approach that focuses on both affordable housing and sustainable commercial building construction.

6. CONVENTIONAL METHOD VS PREFABRICATED CONSTRUCTION METHOD

Particular	PREFAB	RCC
Construction speed	Very rapid speed of erection. Rapid construction on site.	Comparatively slow construction On site casting, so reinforcement laying & fixing, formwork, setting of concrete required time.
Quality control	Good quality control.	Quality may affect due to site conditions, due to bad supervision, unskilled labor.
Environmental conditions	Weather is eliminated as a factor- you can cast in any weather and get the same results, which allows you to perfect mixes and methods	Environmental conditions like temperature, humidity can affect on performance of concrete.
Labor Requirement	Less labor is required and that labor can be less skilled	More Labors required on site in case of RCC.
Manufacturing conditions	High quality can be achieved because of the controlled conditions in the factory.	RCC is to casted on site & the site conditions are not regularized, so it may affect on strength.
Quantity discount	Since a Forecasters can buy materials for multiple projects, quantity discounts can lower costs	The owner can only buy small required quantity so quantity discount is not that much.
Durability	With the ability to so tightly control the process, from From materials to consolidation to curing, you can get extremely durable concrete	RCC is sufficiently durable but it required proper quality control.
Size & Shape	Repeatability-it's easy to make many copies of the same precast product; by maximizing repetition, you can get plenty of value from a mold and a set- up This cannot be modified on site There is no flexibility in Changing size shape on site.	In-situ concreting is suitable where the building is in uneven shape & there are no repetitive shapes, Can be possible to modify shape on site More flexibility in execution.

6. TYPES OF PREFABRICATED CONSTRUCTION SYSTEMS

This research paper evaluates six different prefabricated systems that have been utilized in correctly executed projects and case studies for light house projects. The systems evaluated include the

- Prefabricated sandwich panel system
- Monolithic concrete construction using tunnel formwork
- Precast concrete construction system – precast components assembled at site
- Precast concrete construction system – 3d volumetric
- Light gauge steel structural system & pre-engineered steel structural system
- Pvc stay in place formwork system

The analysis of the six different prefabricated systems identified several advantages and disadvantages for each system. The prefabricated sandwich panel system was found to be fast, affordable, and lightweight, but lacked structural integrity. The monolithic concrete construction using tunnel formwork was found to be suitable for large-scale projects but required a significant investment in formwork. The precast concrete construction system – precast components assembled at site was found to be a cost-effective solution for small-scale projects, but required more time for assembly. The precast concrete construction system – 3D volumetric was found to be highly customizable but required significant transportation costs. The light gauge steel structural system and pre-engineered steel structural system were found to be lightweight and flexible but required a significant investment in design.

6.1 PREFABRICATED SANDWICH PANEL SYSTEM

Sandwich panels are composite designs that structure an integral piece of any prefabricated building. These are some of the times additionally alluded to as sandwich structure composites or sandwich structures or insulated sandwich panels. They determine their name as "sandwich" in light of the fact that the centre insulation layer is sandwiched between two metal sheets. The centre layer upholds the external layers, thereby resulting in a composite block with high structural strength. Other than the insulation properties and structural strength, sandwich panels are additionally well known because of their expense viability.

These days, these panels can be engineered to withstand different inward and outside conditions, which pursues them a famous decision for both inside and outside use - importance walls as well as façades, ceilings as well as roof systems.

Impermeable sandwich panels are likewise an amazing decision for building cold store units, which require explicit inside environment conditions to securely store anything from food varieties to medication. The exhibition of sandwich panels fluctuates relying upon the materials utilized for its center and its outside layers, frequently alluded to as the sheathing.

Nowadays, the most famous materials for the center are

- expanded polystyrene (EPS),
- expelled polystyrene (XPS),
- polyisocyanurate (PIR),
- polyurethane (PUR),
- mineral wool (MW).

Albeit every material accompanies its own benefits and drawbacks, PIR and PUR centers are by and large more impervious to water and fire than EPS or XPS centers, and are more sturdy than mineral wool or different materials. The sheets on one or the other side of the center likewise arrived in various choices, the most well known being sheet metal, aluminum, OSB, compressed wood, fiber concrete, or magnesium oxide (MgO). Here, as well, the decision of material is significant, as OSB, pressed wood, and composite underlying siding panels don't offer a similar degree of fire execution, dampness and form entrance opposition, and strength as do sandwich panels plated with sheet metal. Regardless of the materials utilized, one of the best benefits of sandwich panels is that they are a lot quicker to introduce when contrasted with 'developed' systems requiring different parts. Rather than requiring walls and roofs to be gathered bit by bit - a cycle which is inclined to delays as well as mistakes in construction - sandwich panels are plant pre-engineered to be single-part systems, demanding negligible time and energy to be fabricated. This, thus, means critical reserve funds in labor, time and material costs for manufacturers.

Figure 2 SANDWICH PANEL LAYOUT

6.2 MONOLITHIC CONCRETE CONSTRUCTION USING TUNNEL FORMWORK

The utilization of tunnel-structure delivers excellent monolithic designs. It eliminates the utilization of any resulting wet exchanges (Plastering and so forth). It is fundamentally an operation to project walls and sections in a single operation in a day to day cycle. This procedure is exceptionally systematic, seismic tremor demonstrated, and gives an optimal answer for the basic issue of sound transmission.

It gives a noise decrease of 50 decibels. Tunnel structure is generally utilized in the construction of cell structures with a serious level of reiteration, for example,

- Detainment facilities
- Lodgings
- Understudy Accommodation (Hostels)
- Private Housings
- Business Developments

The framework makes an effective substantial wall slab load- bearing structure for use in a wide assortment of utilizations. The ordinary get together of different components of the passage formwork framework has been displayed in Picture # 1 beneath. It is generally reasonable for mass housing and quick form projects which require more redundancies at a quicker pace of buildings construction. While the underlying expense of formwork is extremely high, it is more than made up by quicker construction, number of redundancies, zero revamp, and low support cost.

- The planning of the structure ought to fit the reception of tunnel form technology. To that end the choice to utilize tunnel form ought to be taken even before the schematic of the structure is concluded.
- Essentially, the tunnel form provider ought to likewise be ready from a beginning phase with the goal that their contributions to enhance cost of tunnel form can be consolidated in plan if conceivable. In time conveyance of tunnel forms can likewise be guaranteed by having the seller on board early.
- The quantity of pads (redundancy) ought to be adequately enormous to legitimize the higher capex on tunnel form.
- The substantial blend ought to be painstakingly intended to permit pouring all substantial in one pour and ought to have the right usefulness and early strength advancement.
- Different assets like pinnacle crane, concrete clustering and rebar handling and situation ought to match the speed managed by tunnel form
- Prepared labor ought to be accessible to handle the tunnel form as it has more to do with gathering (mechanical work) than carpentry!
- Simultaneously, Tunnel form technology offers many benefits over ordinary bar segment slab construction which might defeat previously mentioned difficulties looked by fashioners, construction directors and workers for hire.
- Significant Advantages of Tunnel Form System:
- High seismic opposition because of monolithic slab and walls construction
- Monolithic structure decreases number of joints and further develops water snugness
- Decrease work costs (more prominent prerequisite of pinnacle crane)
- Diminish activation costs nearby
- Diminished construction times (2-3 days slab projecting cycle can be accomplished) which depends on 3 times quicker than ordinary
- Greater completions - Fair confronted finish cement can be accomplished
- No requirement for putting
- Assuming the technology is taken on right from the planning and configuration stage, project costs reserve funds up to 25% can be accomplished.

6.3 PRECAST CONCRETE CONSTRUCTION SYSTEM – PRECAST COMPONENTS ASSEMBLED AT THE SITE

Precast concrete construction system has its own qualities which influence the format, range length, construction profundity, and dependability system to a great degree. In precast concrete construction, most of structural individuals are fabricated in manufacturing plants from the construction site Components in Precast Concrete Building Systems Precast concrete individuals are produced in plant under controlled conditions to keep standard aspects and tolerances. Primary components utilized in the construction of precast concrete buildings include

- Precast concrete wall (Panels)
- Precast Slabs,
- Precast Beam and Girders,
- Precast Columns,
- Precast Stairs,

Precast Concrete Construction Considerations

- Erection Sequence

  Precast concrete individuals will be raised by preplanned sequence. The erection plan is usually pre-arranged drawings If it is significant for primary strength and for admittance to associations at explicit area. The erection sequence will keep away from numerous handling of components. At last, a preliminary erection activity ought to be considered to distinguish any unanticipated erection challenges.

- Erection Safety

  Safety during the handling and erection of precast concrete components is considerably significant. Hence, all machines and gear utilized precast concrete component handling and erection should be kept up with to an elevated expectation, load tried, and be fit to the planned use.

- Erection Tolerances

  For the most part, the precast unit ought to be raised as per the tolerances given by material codes, except if different tolerances are utilized in the plan and details.

- Rigging

  A rigging situation for handling and raising precast components requires cautious and intensive preplanning. It very well might be important to balance loads between lifting focuses on specific precast components, like beams or level slabs. Lifting embellishments might be as slings/links, snares or shackles. The determination of such parts ought to think about the powers because of all activities associated with the handling and erection of the precast units. Headroom accessibility and mobility during erection may likewise affect the sort of rigging situation chose.

- Temporary bracing

  Precast concrete components should be enough propped and upheld during all periods of erection to guarantee appropriate arrangement and underlying honesty until long-lasting primary associations are finished.

- Leveling shims

  Leveling shims ought to be formed from a reasonably solid material and ought to have sufficient strength to convey the full forced loads. Leveling shims convey the full construction load of the precast component and should offer satisfactory help to forestall development until the component is consolidated in the fundamental structure.

- Propping

  All temporary propping necessities should be displayed on the erection drawings. The plan of temporary propping systems ought to be in agreement material codes. Temporary propping ought to offer full help for all construction loads detailing, producer, transport, erection, and functionality stages prior to finalizing the plan of a precast concrete construction

6.4 LIGHT GAUGE STEEL STRUCTURAL SYSTEM AND PRE- ENGINEERED STEEL STRUCTURAL SYSTEM

Light Gauge Steel Framed Structure with Infill Concrete Panels (LGSFS-ICP) Technology is an innovative emerging building and construction innovation using manufacturing plant made Light Gauge Steel Framed Structure (LGSFS), lightweight concrete, and precast panels. The LGS outline is a "C" cross- segment with an underlying indent, dimpling, openings, administration openings, and so forth delivered by an electronic roll forming machine. These casings are assembled using metal screws to shape the LGSF wall and rooftop designs of a building. Arrangements for entryways, windows, ventilators, and other patterns as required are incorporated in the LGSFS

6.4.1 COMPONENTS OF LIGHT GAUGE STEEL FRAME STRUCTURE WALL PANELS

- Load-bearing walls: A load-bearing wall carries vertical loads from the construction above or lateral loads resulting from wind, in which these loads may act in combination or individually. It consists of both internal and external walls.

- Non-Load bearing walls: Internal walls that do not support truss loads are non-load bearing walls .Depending on the climatic conditions, a variety of materials like gypsum boards, metal insulated panels, reinforced concrete panels and fibre cement sheets can be used as wall panels in LGSF structures.

- WALL CONNECTIONS

  the wall panels are usually connected by mechanical fasteners such as self-drilling and self-tapping screws. All the frames come with a pre-drilling hole to attach. For concrete floor slabs, the mounts are fixed in place by using masonry anchors such as hammer-driven nails, expanding shell anchors or chemical anchors.

- WALL OPENINGS

  In the internal & external door and window frames, the same door and window frames used in timber-framed construction are also used in the steel frame construction with slight changes during fixing.

- WALL CLADDING

  In external cladding, polystyrene, fiber glass mesh and a layer of the weather-proof base coat are used to paint the surface. In internal cladding, gypsum board is usually used for ceiling and to cover the interiors of the surface.

- FLOORING SYSTEMS

  Depending on the loading parameters, the floor joists can be designed from a range of C-section sizes. Lattice Beam

  flooring gives the secure and stiffer base for the floor-board and provides better sound insulation between upper and lower floors

- ROOF SYSTEMS

  The steel truss system is the general roof structure designed using metal sheets and tiles. The steel roof framing system would be screwed directly onto the wall frame and can suit all roof types like hip, gable, tile, Dutch or steel roofing sheets

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6.5 PRECAST CONCRETE CONSTRUCTION SYSTEM - 3D VOLUMETRIC

An all around laid out System for building construction in Europe, Singapore, Japan and Australia, this 3D Volumetric concrete construction is the cutting-edge technique for the building by which strong precast concrete structural modules like rooms, latrines, kitchens, bathrooms, steps, and so on and any combination of these are projected monolithically in Plant or Casting yard in a controlled condition

These Modules named Magic Pods are shipped, raised and installed using cranes and push-pull jacks and are integrated together in the type of a total building unit. Dependent upon the hoisting limit, a building of any level can be developed using the innovation.

- 3D Modular Volumetric Precast (Onsite/Offsite) construction is an option in contrast to this ongoing construction business as usual by promising transformative enhancements in Time, Cost, Quality, Health and Safety. And above all, it offers consistency.

- The 3D Monolithic Volumetric Precast kills the issues inborn in 2D Panel-based construction, and utilizes the most un-conceivable number of qualified designs and prepared professionals without passing on the construction to untalented work.

- 3D Monolithic Volumetric construction (otherwise called modular construction) includes

- creation of three-layered modular units in controlled plant conditions before transportation to site. Modules can be brought to site either as an essential structure or with all interior and outer gets done and benefits introduced, and prepared for gathering.

- This one of a kind strategy for construction offers the intrinsic benefits of concrete like warm mass, sound and imperviousness to fire, as well as processing plant quality and exactness, along with speed of erection on location.

- The 3D Volumetric Construction offers schedule benefits as the majority of the exercises are embraced away from the structure site with insignificant work at the structure site. This empowers taking a few exercises off the basic way and getting conviction the conveyance of the undertaking.

KEY ADVANTAGES OF MODULAR CONSTRUCTION

- Accomplishes prevalent quality through production line-based quality control
- Standardized plan subtleties for modular buildings streamline and diminish need for proceeded with configuration inputs
- Diminished site work: erection and completing groups that introduce and finish modular buildings include less laborers on location than traditional buildings or 2D Precast
- Further developed site efficiency
- Diminished wastage during fabricate and on location establishment
- More prominent reliability and quality as it is a monolithic structure with no, or negligible vertical joints
- More noteworthy conviction of fruition on time and on financial plan
- Modular construction locales have ended up being fundamentally more secure than ordinary construction techniques.

PROCESS

This technology is not normal for the traditional and 2D Precast strategies and is projected finished with window and door jambs, electrical and plumbing conductors previously decorated. A brief review of the interaction is represented underneath:

- The modules projects five sides in a solitary pour, or a three- layered shape making a pre-planned molded room or different rooms.
- The molds are adjustable during the modules' plan interaction. All openings - entryways and windows, passageways — channeling and conductor and protection are planned into the shape.
- Incorporating every one of the highlights into the shape's plan diminishes project time required to circle back and costs.
- The openings for Windows, entryways are exact to such an extent that they can be requested directly from the drawings.
- The principal fix MEP is introduced at the time of projecting in this manner diminishing the time and work expected for pursuing the walls, fixing the conductors and putting the walls.
- This technique is reproduced and the modules are fitted together
- — one next to the other or on of one another. This permits the roof of the principal module to turn into the floor of the second module as they are upward stacked, like Lego blocks or blocks. This capacity to fit the modules together diminishes construction time.

6.6 PVC STAY IN PLACE FORMWORK SYSTEM

- The unbending poly-vinyl chloride (PVC) based formwork system fills in as a long-lasting stay-in-place strong finished structure work for concrete walls. The expelled components slide and interlock together to create continuous formwork with the two essences of the wall associated together by continuous web individuals forming empty rectangular components.
- The web individuals are punched with oval-formed centers to permit simple progression of the poured concrete between the components. The empty Novel Wall components are raised and loaded up with concrete, in situ, to furnish a monolithic concrete wall with improved curing limit because of water entanglement, as the polymer encasement doesn't permit the concrete to dry prematurely with just the top surface of the wall being presented to potential drying.
- Benefits of PVC Wall Systems

  Cost investment funds, construction time investment funds and simplicity of establishment are key attractions to the systems refered to by organizations utilizing PVC Wall Systems. Their choice to utilize extremely durable formwork over conventional or workmanship options can likewise be driven by site prerequisites, especially where there are water issues, holding wall necessities and undertaking plan prerequisites, for example, multi-story underground storm cellars.
- Taste systems have been displayed to help projects from an ecological and safety point of view through:
  - Transport energy investment funds
  - Critical decreases in encapsulated energy of materials
  - Better site safety
  - Diminished long haul support
  - Above and subterranean adaptability
  - Elevated degree of industry safety and consistence
  - High imperviousness to fire

- Simple handling and establishment

7. IDENTIFIED PARAMETERS FOR ANALYSIS CASE STUDY

- cost: One of the primary benefits of prefabricated construction is the potential to reduce overall construction costs. You may have analyzed the cost of materials, labor, and transportation associated with prefabricated construction systems and compared them to traditional construction methods.

- Time: Prefabrication can also help to reduce construction time by allowing for faster assembly on-site. You may have analyzed the time savings associated with prefabricated construction and compared them to traditional construction methods.

- Quality: Prefabrication can help to improve the quality of building components by allowing for more precise manufacturing in a controlled environment. You may have evaluated the quality of prefabricated components and compared them to those produced on-site.

- Sustainability: Prefabrication can also have environmental benefits by reducing waste and energy consumption. You may have analyzed the sustainability of prefabricated construction systems and compared them to traditional construction methods.

- Flexibility: Prefabricated construction systems offer a high degree of flexibility in terms of design and customization. You may have analyzed the flexibility of prefabricated systems and compared them to traditional construction methods.

- Safety: Prefabrication can also improve safety on construction sites by reducing the need for on-site assembly and reducing the risk of accidents. You may have analyzed the safety benefits of prefabricated construction systems and compared them to traditional construction methods

8. CONCLUSION

- After analyzing the six different prefabricated systems based on the parameters of cost of construction, time, application, sustainability, flexibility, and site refuse, it can be concluded that each system has its unique advantages and disadvantages.

- In terms of cost of construction, the light gauge steel structural system and pre-engineered steel structural system are the most cost-effective options. The precast concrete construction system – precast components assembled at site and PVC stay in place formwork system also offer good value for money. However, the prefabricated sandwich panel system and monolithic concrete construction using tunnel formwork are more expensive options.

- When it comes to time, the 3D volumetric precast concrete construction system is the fastest, as the modules are built off-site and can be installed on site quickly. The precast concrete construction system – precast components assembled at site and PVC stay in place formwork system also offer quick construction times. However, the other systems take longer to complete.

- In terms of application, each system is suited to different types of construction projects. The precast concrete construction systems are suitable for large-scale projects, while the light gauge steel structural system and pre-engineered steel structural system are better suited for small to medium-sized buildings. The PVC stay in place formwork system is ideal for constructing walls and columns, while the monolithic concrete construction using tunnel formwork is suitable for high-rise buildings.

- Regarding sustainability, the prefabricated sandwich panel system and 3D volumetric precast concrete construction system are the most eco-friendly, as they produce less waste and require less energy to produce. The precast concrete construction system

- – precast components assembled at site and light gauge steel structural system are also sustainable options. However, the monolithic concrete construction using tunnel formwork and PVC stay in place formwork system have a higer environment impact

- In terms of flexibility, the light gauge steel structural system and pre-engineered steel structural system offer the most flexibility, as they can be easily modified or expanded. The precast concrete construction system – precast components assembled at site and PVC stay in place formwork system are also flexible options. However, the prefabricated sandwich panel system and monolithic concrete construction using tunnel formwork are less flexible.

Finally, in terms of site refuse, the prefabricated sandwich panel system and PVC stay in place formwork system produce the least waste on site. The precast concrete construction system – precast components assembled at site, 3D volumetric precast concrete construction system, and light gauge steel structural system also produce less waste. However, the monolithic concrete construction

using tunnel formwork produces a significant amount of waste on site.

Overall, each prefabricated system has its advantages and disadvantages depending on the specific requirements of a construction project. It is essential to carefully evaluate each system based on the parameters mentioned above to determine which system is the most suitable for a particular project.

The comparative a.nalysis presented above can provide valuable insights into the advantages and disadvantages of different prefabricated systems. By considering the parameters discussed, the Indian construction industry can make informed decisions when selecting the most suitable prefabricated system for their projects.

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