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Utilization of ferrocement to rural sanitation

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ABSTRACT

Engineering is the application of technology for the benefit of society, and it encompasses various fields based on specific areas of application. Civil engineering, in particular, plays a crucial role in the construction and maintenance of infrastructure such as roads, bridges, dams, canals, and buildings. This project focuses on the utilization of civil engineering principles for the "Application of Ferrocement Technique to the Rural Sanitary Block System." The escalating costs of basic building materials like steel, sand, cement, brick, timber, and labor have led to a continuous rise in construction expenses. Conventional building materials and construction techniques are becoming less economical, especially for low and middle-income groups. Therefore, there is an urgent need to explore cost-effective construction techniques, either by upgrading conventional methods or by introducing innovative approaches. Ferrocement panels, the key focus of this project, offer a practical solution. These panels are easy to cast, cure, and manually erect on-site. The roofing system developed through ferrocement technology provides strength and rigidity, making it a cost-effective alternative. This makes it particularly well-suited for prefabricated construction, especially beneficial for people residing in rural areas. In essence, this project aims to leverage civil engineering principles to address the economic challenges associated with construction. By introducing ferrocement techniques, it seeks to provide a viable and cost-effective solution that can benefit not only low-income populations but also middle-income groups, contributing to sustainable and affordable construction practices in the realm of rural sanitation.

Keywords: *Ferrocement Technology, Rural Sanitation, Construction Techniques, Prefabricated Construction*.

I. INTRODUCTION

Sanitation is crucial for achieving certain global development goals, especially in countries like India with a rapidly growing population. The Indian government has implemented various policies, such as Nirmal Bharat Abhiyan and Total Sanitation Campaign, to address this issue. However, progress has been slow, prompting the government to set a new target for completion by 2022.

One proposed solution to expedite sanitation efforts involves using a construction material called ferrocement. Ferrocement is a strong and versatile form of reinforced concrete made from wire mesh, sand, water, and cement. It is easy to work with and requires minimal skilled labor. This material has applications in various sectors, including building, irrigation, and sanitation.

Studies suggest that ferrocement is particularly effective in constructing earthquake-resistant structures. Unlike traditional reinforced concrete, ferrocement doesn't require complex formwork or welding, making it cost-effective and suitable for areas where labor costs are low. The main difference lies in the use of closely spaced small diameter wire meshes instead of larger rods and aggregates.

Ferrocement has a thickness ranging from 25 to 50 mm, and the latest standards encourage the use of non-metallic reinforcement and fibers. It is an eco-friendly technology with properties such as good tensile strength, toughness, water resistance, lightweight, fire resistance, and crack resistance. In simpler terms, ferrocement is a thin, strong material made by reinforcing cement with closely spaced wire mesh layers, offering a practical and efficient solution for construction.

Present scenario of Sanitation system in India

Clean water, good sanitation, and proper hygiene are essential for a healthy and improved quality of life for everyone. An alarming 88% of diseases worldwide are linked to unsafe drinking water, inadequate sanitation, and poor hygiene practices. Shockingly, approximately 40% of the global population, totaling 2.5 billion people, lacks access to proper sanitation facilities. In India alone, nearly 638 million people resort to open defecation due to the absence of adequate sanitation infrastructure.

This widespread lack of sanitation not only poses a threat to people's health but also has adverse effects on the environment. Despite various governmental programs and initiatives in India aimed at addressing these challenges, many communities still do not have access to adequate sanitation and hygiene facilities.

The creation of effective sanitation infrastructure and public services that cater to everyone, especially those in impoverished communities, while also managing waste responsibly, presents a significant challenge. Schools are pivotal not only for imparting education but also for fostering a conducive learning environment. They play a crucial role in the cognitive and creative development of children.

While ensuring access to clean water and proper sanitation facilities in schools is crucial, it is equally important to address behavioral aspects related to sanitation and hygiene. The habits and practices of individuals significantly impact the overall effectiveness of these facilities.
Diarrhea, a consequence of poor sanitation and hygiene, claims the lives of approximately 1.5 million children worldwide each year. It profoundly affects their mental, physical, and immune system development.

Thus, it is imperative to not only provide infrastructure but also to promote and instill good hygiene practices within communities, particularly in schools. This holistic approach is vital for creating a healthy and positive learning environment that contributes to the overall well-being and development of children.

II. PROJECT OBJECTIVES

The goal of ensuring that everyone has access to a toilet is crucial, especially considering that, even in the 21st century, around 1.1 billion people worldwide (in 10 countries) lack this basic facility, with India accounting for almost 638 million of them.

The primary objective of the project is to spread, advocate, and implement safe, durable sanitation technologies to improve the living conditions of rural communities. Simultaneously, the project aims to enhance the skills of local construction workers. This will be achieved through extensive awareness programs, training initiatives, on-site demonstrations, and fostering entrepreneurship in rural areas, particularly in the production of building materials and the adoption of appropriate sanitation technologies.
The project's activities revolve around the 3A’s AS framework:

Awareness: The project seeks to organize programs that create awareness about suitable rural sanitary facilities among the rural population. This involves conducting seminars and utilizing mass communication mediums such as newspapers to reach a wider audience.
Acceptance: Building confidence among rural communities, artisans, and field engineers is a key focus. This is accomplished through live demonstrations showcasing newer technologies and promoting on-site construction of model demonstration housing using innovative materials and construction methods.

Application: The project aims to mobilize and support the application and use of appropriate research and development (R&D) and technologies in the public domain. The goal is to create visible impacts within the community by encouraging the widespread adoption of these technologies.

These objectives further aim to:
*Develop skilled manpower: By providing training locally, the project seeks to develop a pool of trained and skilled workers and artisans. This contributes to enhancing productivity and the employment potential of construction workers in the construction sector.

*Promote mass-scale adoption: The project aims to motivate government and development organizations, as well as the end-users, for the widespread commercialization and adoption of appropriate sanitation technologies.

In summary, the project envisions a comprehensive approach, incorporating awareness-building, confidence-building through live demonstrations, and active promotion and application of appropriate sanitation technologies. The ultimate goal is to improve the living conditions of rural communities and contribute to the overall development of the construction sector in the region.

Government initiatives

Government of India has been running many schemes since last many years. Let us analyse these schemes.

Central Rural Sanitation Programme (CRSP)

Central Rural Sanitation Programme (CRSP) was launched in 1986 with the objective of improving the quality of life of the rural people and also to provide privacy and dignity to women by providing proper sanitation facilities in rural areas.

Nirmal Bharat Abhiyan and Total Sanitation Campaign

The concept of sanitation was further expanded to include personal hygiene, home sanitation, safe water garbage and excreta disposal and waste water disposal with the name "Total Sanitation Campaign" (TSC) with effect from 1999. Individual toilets, community sanitation complexes, institutional toilets and solid and liquid waste water systems are constructed under the scheme. The key feature of this scheme is role of CSOs, Community Based Organisations (CBOs) and Panchayati Raj Institutions (PRIs) is very important. It has been recently allowed that certain component of the toilet construction can be taken from Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA) with a maximum ceiling of 4500 Rupees per unit only. Whereas Rupees 3200 Rupees comes from central Government and 900 Rupees is beneficiary's share. States usually give amount of approximately half of the amount provided by central Government. This is sufficient only to build basic structure (substructure) of individual two pit pour flush toilet.

Nirmal Gram Puraskar

To add motivation to this scheme, GOI launched an award based Incentive Scheme for fully sanitized and open defecation free Gram Panchayats, Blocks, Districts and States called "Nirmal Gram Puraskar" (NGP) in October 2003. Till the date many villages have been awarded to bring in motivation among the people specially PRI functionaries at village level to make NBA a success.

Ferrocement in general

Ferrocement is a form of reinforced concrete that differs from conventional reinforced or prestressed concrete primarily by the manner in which the reinforcing elements are dispersed and arranged. It consists of closely spaced, multiple layers of mesh or fine rods completely embedded in cement mortar. A composite material is formed that behaves differently from conventional reinforced concrete in strength, deformation, and potential applications, and thus is classified as a separate and distinct material. It can be formed into thin panels or sections, mostly less than 1 in. (25 mm) thick, with only a thin mortar cover over the outermost layers of reinforcement. Unlike conventional concrete, ferrocement reinforcement can be assembled into its final desired shape and the mortar can be plastered directly in place without the use of a form. The term ferrocement implies the combination of a ferrous reinforcement embedded in a cementitious matrix. Yet there are characteristics of ferrocement that can be achieved with reinforcement other than steel meshes or rods. For instance, the ancient and universal method of building huts by using reeds to reinforce dried mud (wattle and daub) could be considered a forerunner of ferrocement. The use of non-metallic mesh is being explored at several universities. Such meshes include woven alkali resistant glass, organic woven fabrics such as polypropylene, and organic natural fabrics made with jute, burlap, or bamboo fibres. Therefore, the term ferrocement currently implies the use of other than steel material as reinforcement. The following definition was adopted by the Committee: "Ferrocement is a type of thin wall reinforced concrete commonly constructed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small size wire mesh. The mesh may be made of metallic or other suitable materials."

III.GENERAL MATERIAL & METHODOLOGY

The material used in ferrocement consists primarily of mortar made with Portland cement, water and aggregate and the reinforcing mesh. Cement The cement shall comply with ASTM C150-85a, ASTM C595-85, or an equivalent standard. The cement shall be fresh, of uniform consistency, and free of lumps and foreign matter. It shall be stored under dry conditions for as short a duration as possible. The choice of a particular cement shall depend on the service conditions. Service conditions can be classified as electrochemically passive or active. Land based structures such as ferrocement silos, bins, and water tanks can be considered as passive structures, except when in contact with sulphate bearing soils, in which case the use of sulphate resistant cement, such as ASTM Type II or Type V, may be necessary. Blended hydraulic cement conforming to ASTM C595-85 Type 1 (PM), IS, 1 (SM), IS-A, IP, or IP-A can also be used. Mineral admixtures, such as fly ash, silica fumes, or blast furnace slag, may be used to maintain a high volume fraction of fine filler material. When used, mineral admixtures shall comply with ASTM C618-85 and C989-85a. In addition to the possible improvement of flow ability, these materials also benefit long term strength gain, lower mortar permeability, and in some cases improved resistance to sulphates and chlorides.

Aggregates

Aggregate used in ferrocement shall be normal weight fine aggregate (sand). It shall comply with ASTM C33-86 requirements (for fine aggregate) or an equivalent standard. It shall be clean, inert, free of organic matter and deleterious substances, and relatively free of silt and clay. The grading of fine aggregate shall be in accordance with the guidelines of Table No 3.1 However, the maximum particle size shall be controlled by construction constraints such as mesh size and distance between layers. A maximum particle size passing sieve No. 16 (1.18 mm) may be considered appropriate in most applications. The sand shall be uniformly graded unless trial testing of mortar workability permits the use of a gap graded sand. Aggregates that react with the alkalis in cement shall be avoided. When aggregates may be reactive, they shall be tested in accordance with ASTM C227-81. If proven reactive, the use of a pozzolona to suppress the reactivity shall be considered and evaluated in accordance with ASTM C441-81.

Table1: Guidelines for Grading of Sand

Sieve Size U.S. Standard Square Mesh	**Percent passing by weight**
No.8 (2.36mm) No.16 (1.18mm)	80-100 50-85

No,30 (0.60mm)	25-60
No.50 (0.30mm)	10-30
No.100 (0.15mm)	2-10

Water

The mixing water shall be fresh, clean, and potable. The water shall be relatively free from organic matter, silt, oil, sugar, chloride, and acidic material. It shall have a pH ≥ 7 to minimize the reduction in pH of the mortar slurry. Salt water is not acceptable, but chlorinated drinking water can be used.

Admixtures

Conventional and high range water reducing admixtures (super plasticizers) shall conform to ASTM C494-86. Water reducing admixtures may be used to achieve an increase in sand content for the same design strength or a decrease in water content for the same workability. Decreases in water content result in lower shrinkage and less surface crazing. Retarders may be used in large time consuming plastering projects, especially in hot weather conditions. If water tightness is important, such as in water or liquid retaining structures, special precautions shall be taken. To achieve water tightness, the water cement ratio shall preferably be kept below 0.4, crack widths limited and, if necessary, waterproofing coatings applied. Mineral admixtures such as fly ash (ASTM C618-85) can be added to the cement to increase workability and durability. Normally, 15 per cent of the cement can be replaced with mineral admixtures without appreciably reducing the strength. Pozzolonic admixtures may be added to replace part of the fine aggregates to improve plasticity. The tendency for some natural pozzolonas to absorb water and thus adversely affect hydration of the cement phase shall be checked by measuring the water of absorption. A quality matrix can be obtained without using any admixtures if experience has shown its applicability. Admixtures not covered in ASTM standards shall not be used.

Mix Proportioning

The ranges of mix proportions for common ferrocement applications shall be sand cement ratio by weight, 1.5 to 2.5, and water cement ratio by weight, 0.35 to 0.5. The higher the sand content, the higher the required water content to maintain the same workability. Fineness modulus of the sand, water cement ratio, and sand cement ratio shall be determined from trial batches to ensure a mix that can infiltrate (encapsulate) the mesh and develop a strong and dense matrix. The moisture content of the aggregate shall be considered in the calculation of required water. Quantities of materials shall preferably be determined by weight. The mix shall be as stiff as possible, provided it does not prevent full penetration of the mesh. Normally the slump of fresh mortar shall not exceed 50 mm. For most applications, the 28 day compressive strength of 75 by 150 mm moist cured cylinders shall not be less than 35 N/mm2.

Reinforcement

The reinforcement shall be clean and free from deleterious materials such as dust, loose rust, coating of paint, oil, or similar substances. Wire mesh with closely spaced wires is the most commonly used reinforcement in ferrocement. Expanded metal, welded wire fabric, wires or rods, prestressing tendons, and discontinuous fibres may also be used in special applications or for reasons of performance or economy.

Wire Mesh

Reinforcing meshes for use in ferrocement shall be evaluated for their susceptibility to take and hold shape as well as for their strength performance in the composite system.

Welded Wire Fabric

Welded wire fabric may be used in combination with wire mesh to minimize the cost of reinforcement. The fabric shall conform to ASTM A496-85 and A497-86. The minimum yield strength of the wire measured at a strain of 0.035 shall be 410 N/mm2. Welded wire fabric normally contains larger diameter wires (2 mm or more) spaced at 25 mm or more.

Expanded Metal Mesh Reinforcement

Expanded mesh reinforcement (metal lath), formed by slitting thin gauge steel sheets and expanding them in a direction perpendicular to the slits, may be used in ferrocement. Punched or otherwise perforated sheet products may also be used. Expanded mesh is suitable for tanks if proper construction procedures are adopted.

Bars, Wires and Prestressing Strands

Reinforcing bars and prestressing wires or strands may be used in combination with wire meshes in relatively thick ferrocement elements or in the ribs ofribbed or T-shaped elements. Reinforcing bars shall conform to ASTM A615-86, A616-86 or A617-84.Reinforcing bars shall be steel with a minimum yield strength of 410 N/mm2 and a tensile strength of about615 N/mm2. Prestressing wires and strands, whether prestressed or not shall conform to ASTM A421-80 and A416-86, respectively.

Discontinuous Fibres and Non-metallic Reinforcement

Fibre reinforcement consisting of irregularly arranged continuous filaments of synthetic or natural organic fibres such as jute and bamboo may be used in ferrocement. If organic materials are used, care shall be taken to conduct appropriate investigations to ensure the strength and durability of the finished ferrocement product.

IV. FUTURE SCOPE AND APPLICATION

Future scope

This project not only ensures cost-effectiveness but also prioritizes environmentally friendly sanitary blocks. The focus is intentionally directed towards rural areas, where approximately 70% of the population resides, and a significant portion engages in agriculture, with many belonging to the weaker sections of society. The importance of this initiative lies in the present need for structures that are:
Cost-effective: The project aims to create sanitary blocks that are affordable, ensuring that even the lowest income groups can access them.

Lightweight: The structures designed are lightweight, making them easy to install and maintain.

Speedy to construct: The emphasis is on construction methods that are quick and efficient, addressing the urgent need for improved sanitation facilities.

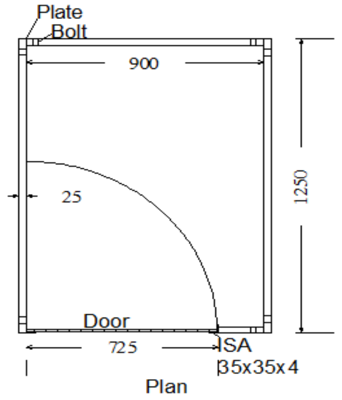
Affordable to the lowest income group: Ensuring accessibility to the lowest income groups is a key consideration, aligning with the goal of inclusive development.

In a country like India, where achieving cleanliness is a national objective, the proper implementation of such projects becomes crucial. This involves extending these initiatives to every school, anganwadi (childcare center), and household. The economic losses incurred each year due to poor sanitation are substantial. Implementing projects of this nature has the potential to save significant amounts, running into lakhs of crores, annually.

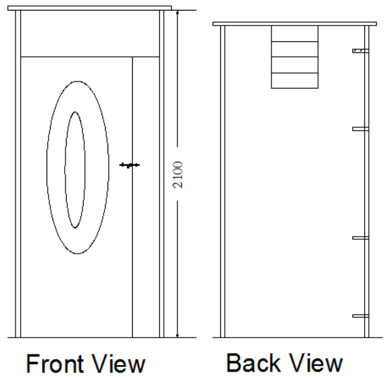
The broader impact of such an initiative goes beyond immediate economic gains. It contributes to improved public health, enhanced living conditions, and aligns with the larger vision of creating a cleaner and healthier environment for all. By targeting schools, anganwadis, and households, the project addresses key areas of community life, ensuring a more widespread and lasting impact on the overall well-being of the population.

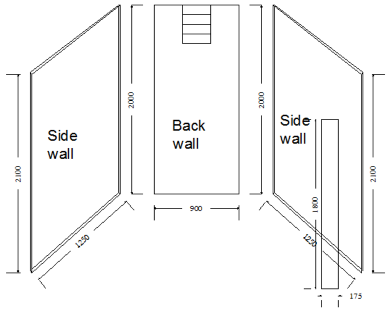
Economic losses per year due to poor sanitation
Loss to individual: Rs 2500
Loss to a family with 4 members: Rs 10,000
Loss to a village with 1000 household: Rs 1 crore
Loss to India: Rs 2,70,000 crores

V. DESIGN OF MODEL



Top View





3-D View

VI. CONCLUSION

1. Ferrocement panels, being precast products, accelerate construction speed and enable building construction even in adverse weather conditions.
2. At service loads, ferrocement exhibits numerous smaller cracks, in contrast to a few wider cracks seen in reinforced concrete.
3. Utilizing ferrocement panels with higher ductility enhances structural resilience, reducing susceptibility to seismic damage.
4. Increasing the number of mesh layers enhances the ductile behavior of ferrocement slabs.
5. Significant cost reduction, with a 40% lower cost compared to conventional construction techniques.
6. The versatility of ferrocement allows fabrication in any desired shape, making it well-suited for special structures such as shells, roofs, silos, water tanks, and pipelines.
7. The construction of ferrocement panels requires less material, contributing to its environmentally friendly nature.
8. Reduced use of cement and steel in comparison to Reinforced Concrete (RCC) results in a corresponding decrease in self-weight.
9. This technique eliminates the need for scaffolding, shuttering, concrete mixers, or vibrators, streamlining the construction process.

VII. ACKNOWLEDGEMENT

It gives me immense pleasure to present my Synopsis Report on “Application of Technique to the Rural Sanitation System [Ferrocement Detachable Toilet Unit]” and to express my deep regards towards those who have offered their valuable time and guidance in my hour of need. I would like to express my sincere and whole-hearted thanks to my project guide Mr. Sagar Mungase and Head of Department Mrs. Cissy Shaji for contributing their valuable time, knowledge, experience and guidance in making this project successfully done. I am also glad to express my gratitude and thanks to my college Bharati Vidyapeeth Institute of Technology, Navi Mumbai and Respected Principal Mr. P.N. Tandon for continuous inspiration and encouragement. This report helped me to learn new techniques, developments taking place in Civil Engineering and to revise some previous concepts. Indeed I perceive this opportunity as a milestone in my career development. Last but not the least, I sincerely thank to my colleagues, the staff and all others who directly or indirectly helped me and made numerous suggestions which have surely improved the quality of my work.

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