International Journal of Recent Advances in Multidisciplinary Topics
Volume 5, Issue 5, May 2024
https://www.ijramt.com | ISSN (Online): 2582-7839

Strengthening of Retrofitting Using Short Column

V. A. Anulekshmi[1*], B. Siyad[2], H. S. Kunjamina[3], N. Muhammed Nihal[4], P. S. Neena[5], N. Nishad[6]

[1,2,3,4]UG Student, Department of Civil Engineering, Travancore Engineering College, Oyoor, Kollam, India
[5,6]Assistant Professor, Department of Civil Engineering, Travancore Engineering College, Oyoor, Kollam, India

***Abstract*: This study incorporates an experimental investigation aimed at evaluating the effectiveness and suitability of high-performance ferrocement mortar mixes as a retrofitting material. The experimental program involves the development of a high-performance ferrocement mortar mix by incorporating 10% silica fumes, which is subsequently utilized in retrofitting short column specimens that were either intact or distressed to a certain level. The experimental setup encompasses the testing of six controlled specimens and six retrofitted specimens. The controlled specimens, measuring 100mm x 100mm in cross-section and 500mm in height, are cast using M25 conventionally vibrated concrete. These specimens are reinforced longitudinally with four bars of 6mm diameter and six lateral ties of 6mm diameter serving as transverse reinforcement. The jacket of the specimens is reinforced with mild steel welded wire mesh, sized at 50mm x 50mm and made of 1.16mm diameter wire. The retrofitted specimens undergo testing after 28 days of curing. The addition of silica fume is integral to the experiment, enhancing the dispersion of fibers and improving the strength properties of the mortar mix, particularly its impact resistance. Previous studies have demonstrated that the inclusion of silica fume increases compressive, split tensile, and flexural strength, thereby enhancing the overall performance of concrete under impact loading conditions. A detailed examination of curing conditions is conducted, with half of the specimens allowed to cure naturally while the remaining half are cured in a controlled environment within a curing tank. Nevertheless, the study underscores the necessity for further investigations to comprehensively understand the efficiency of cracking and its implications on the retrofitting process.**

***Keywords*: Ferro-cement, Silica fume.**

1. Introduction

Ferro-cement, known for its remarkable strength-to-weight ratio, durability, and crack resistance, has become increasingly popular in construction due to its versatility and eco-friendliness. With a growing emphasis on sustainable practices, researchers are exploring ways to further enhance ferro-cement performance while minimizing its environmental impact. One promising avenue is the incorporation of silica fume, a byproduct of silicon and ferrosilicon alloy production, as a partial replacement for conventional cement. Silica fume, renowned for its ultrafine particle size and high pozzolanic reactivity, offers potential improvements in mechanical properties, durability, and long-term performance when added to ferrocement mixes. By densifying the cementitious matrix, silica fume can reduce permeability and enhance overall structural durability. Additionally, this study aims to

investigate the mechanical behavior of ferrocement specimens, including factors such as compressive strength, flexural strength, and bond strength between the matrix and reinforcement. In the realm of structural engineering, retrofitting stands as a critical intervention to fortify existing buildings against a myriad of environmental and operational hazards. With seismic activity posing a perennial threat to urban landscapes, the imperative to enhance structural resilience has become increasingly pronounced. Amidst this backdrop, the integration of short columns within retrofitting frameworks has emerged as a salient strategy to augment structural robustness and mitigate seismic vulnerabilities. Unlike conventional retrofitting methodologies, which often entail significant structural alterations and resource-intensive procedures, short column strengthening offers a compelling alternative characterized by its efficacy and feasibility. The rationale behind incorporating short columns lies in their ability to redistribute loads, enhance lateral stiffness, and confine potential damage during seismic events. By strategically positioning short columns at key structural nodes, engineers can effectively bolster the overall performance of existing buildings without necessitating extensive modifications to the original design. Moreover, the versatility of short column strengthening techniques renders them adaptable to diverse structural configurations, ranging from reinforced concrete frames to steel structures. Whether employed in conjunction with other retrofitting measures or as standalone interventions, short columns offer a nuanced approach to enhancing structural resilience tailored to the specific exigencies of each building. However, despite their potential benefits, the implementation of short column retrofitting entails various technical challenges and design considerations that warrant meticulous attention. Against this backdrop, this journal embarks on a comprehensive exploration of short column strengthening techniques in the context of retrofitting existing buildings. Through an in-depth analysis of theoretical frameworks, numerical simulations, and empirical case studies, we endeavor to elucidate the efficacy, challenges, and best practices associated with integrating short columns within retrofitting strategies. By synthesizing theoretical insights with practical applications, this study endeavors to furnish engineers and stakeholders with a nuanced

*Corresponding author: anulekshmi580@gmail.com

understanding of the role of short columns in fortifying infrastructure against seismic risks, thereby contributing to the advancement of resilient built environments.

2. Materials and Methodology

A. Materials

1) Ferrocement

Ferrocement, a versatile construction material, comprises cement mortar reinforced with layers of mesh or metal screening, often in the form of chicken wire or metal screens. The matrix of ferrocement typically consists of Portland cement mortar, comprising cement, sand, and water. Reinforcement is provided by layers of mesh or metal screening, commonly made of galvanized iron, steel, or other alloys. The mix proportion for the ferrocement in the range of 1:2.

2) Fine aggregate

Fine aggregate, when combined with cement and water, forms the mortar matrix within ferrocement structures. This matrix encases and binds the reinforcement, imparting strength and cohesiveness to the entire system. For optimal results, sharp sand (M sand) devoid of non-crystalline minerals is recommended, with a maximum allowable grain size of 2.36mm. Well-graded sand, containing a variety of particle sizes, is often preferred to enhance packing efficiency and minimize voids within the mix.

3) Coarse Aggregate

Coarse aggregates, such as sand, gravel, or crushed stone, are irregular and granular materials commonly used in concrete production. These aggregates are often obtained from quarries through blasting or crushing processes. Typically, coarse aggregates are materials that are retained on the 4.7mm sieve size and can reach a maximum size of 63mm. Larger aggregates have a smaller bondable surface area for cement, sand, and water, resulting in reduced water and fine aggregate requirements in concrete mixes. Moreover, the size of the coarse aggregate influences the cement-to-water ratio in the concrete mix.

4) Silica fume

Silica fume, also referred to as micro silica, is a byproduct of silicon metal and ferrosilicon alloy production. Renowned for its highly reactive pozzolanic nature, it interacts with calcium hydroxide in the presence of water, forming additional cementitious compounds. Frequently employed as an additive in concrete and ferrocement mixes, silica fume enhances various properties. Silica fume facilitates the development of a denser and more compact microstructure within the matrix, leading to improved mechanical properties and durability.

5) Steel Reinforcement

Reinforcing steel, often referred to as rebar and mesh, is typically made from carbon steel that undergoes hot rolling to create ribbed profiles, enhancing its bond with concrete. This steel is manufactured from iron ore and recycled steel in various steel mills worldwide. While iron ore serves as an excellent raw material, the use of recycled steel offers advantages such as energy efficiency and reduced pollution, contributing to the conservation of natural resources. Rebar and mesh, crucial components in concrete construction, provide additional strength to concrete structures. Concrete, weak in tension but strong in compression, benefits from the tensile strength of steel reinforcement. Rebars, with plain and round surfaces, come in sizes ranging from 6 mm were used. and find applications in various concrete structures, including expansion joints and contraction joints in roads and runways.

Table 1
Material test

Test Name	Silica Fume	Cement
Compressive strength at 7 days	31.74	18.92
Compressive strength at 28 days	51.54	44.21
Consistency	36%	34%
Initial setting	180	45
Final setting	600	530
Specific gravity	2.86	3.08
Fineness	8%	10%

B. Methodology

In the realm of structural engineering, short columns, often referred to simply as "columns," are vertical structural members designed to support loads primarily through axial compression. The methodology for analyzing and designing short columns involves several key steps:

Determine the loads that the column will be subjected to, including dead loads (permanent, fixed loads like the weight of the structure itself) and live loads (variable loads such as occupants, furniture, wind, and seismic forces). Identify the material properties of the column material, typically concrete, steel, or composite materials. This involves understanding the compressive strength, yield strength, modulus of elasticity, and other relevant properties. Determine the geometry of the column, including its cross-sectional shape, dimensions, and length. Common shapes include rectangular, circular, and square. Conduct a structural analysis to determine the internal forces (primarily axial compression) and moments experienced by the column. This analysis may involve hand calculations or computer software, depending on the complexity of the structure. Refer to applicable design codes and standards (such as the American Concrete Institute (ACI) or American Institute of Steel Construction (AISC) codes) to establish design criteria for the column, including safety factors, allowable stresses, and detailing requirements. Calculate the ultimate axial load-carrying capacity of the column based on its geometry, material properties, and boundary conditions. Ensure that this capacity exceeds the maximum expected loads with appropriate safety margins. If the column is made of reinforced concrete, design the reinforcing bars to provide adequate strength and ductility to resist the applied loads and ensure proper detailing to achieve the desired behavior under loading conditions. Consider the connections between the column and other structural elements, such as beams, slabs, and foundations, to ensure proper load transfer and structural stability. Review the design for accuracy, completeness, and compliance with applicable codes and standards. Iterate as necessary to optimize the design for performance, economy, and constructability. Throughout the methodology, must also consider factors such as column slenderness, buckling, and the effects of imperfections on column behavior. Additionally, considerations for seismic design may be necessary depending on the location and intended use of the structure.

Fig. 1. Whitewashed specimen

Fig. 2. Column covered

3. Mix Design

Mix design of test specimen is done in M25 grade concrete 1:1:2 on the basis of IS code 456:200 and the mix design of the retrofitting id done in 1:2 on the basis of IS code No.13356:1992. The mix had done for 6 specimen of conventional and 6 specimen of retrofitting. The material for each mix were calculated and displayed on the table 2.

Table 2
Mix design

Materials	Weight (kg)	10% replacement (kg)	Total weight (kg)
Cement	33.71	29.83	63.54
Coarse aggregate	54	54	108
Fine aggregate	45	45	90
Silica fume	----	3.5	3.5
Water	28	28	56

4. Workability Test

There are two methods for the determination of the workability. Slump cone and compaction factor test are the tests were conducted. The value of slump and workability is high for the mix of retrofitting by the 10% replacement of the SF as compared to the other mixes. So, the workability become increase for the mixes.

5. Test Specimen

Collect all necessary materials for the concrete mixes, including cement, aggregates, water, steel reinforcement, and supplementary cementations materials (SF). Conduct material tests to ensure they fall within acceptable ranges for quality and performance. Develop mix designs for both retrofitting and conventional concrete specimens. For retrofitting, use a mix ratio of 1:2, while for conventional concrete, adhere to the M25 grade mix design. Calculate the total amounts of materials required for casting based on the mix designs. Prepare 3 specimens each for retrofitting, conventional concrete, 10% SF replacement in retrofitting, and 10% SF replacement in conventional concrete. The retrofitting had done on the test specimen in the size of 100x100x150mm and after remolding the test specimen it is then casted on the mold of size 150x150x500mm. Conduct workability tests such as slump cone and compaction factor tests to ensure proper consistency of the mixes. Cast the specimens according to the respective mix designs. Cure the specimens under standard conditions for 28 days. After curing, white wash the specimens for better visibility during testing. Use a universal testing machine to conduct tests on the specimens, including loading until failure to measure first crack load, ultimate load, displacement ductility, and energy absorption capacity. Analyze the results obtained from the tests to compare the performance of retrofitting and conventional concrete specimens. Evaluate the influence of SF replacement on the properties and behavior of both types of specimens. The figure 3 below shows the universal testing machine.

Fig. 3. Universal testing machine

6. Reinforcement Setup

Typically, 6 mm steel reinforcement bars are used, arranged within the mold. The spacing for a 6 mm diameter bar is usually set at 100 to 100 spacing, with a cover of 25 mm from both sides to ensure adequate protection. These 6 mm bars are easily bent and cut using standard tools. Standard hook lengths for these bars are often specified as 6 times the diameter of the bar, with a minimum length of 75 mm. In terms of stirrups for the reinforcement, two common sizes are utilized: 7x7 mm and

12x12 mm. These stirrups provide additional support and reinforcement within the structure, enhancing its overall strength and stability.

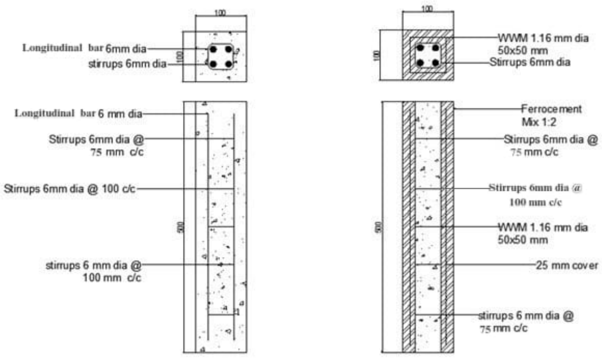

Fig. 4. Schematic representation of retrofitting and control mix

7. Test Result and Discussion

A. Ultimate Load, Displacement Ductility, First Crack Load

Table 3
Average ultimate load, displacement ductility, first crack load

Designation	Ultimate load (KN)	Displacement ductility	First crack load (KN)
M C	613.32	3.365	220
M C10	633.32	3.834	263.33
M R	1240	4.45	393.33
M R10	1350	5.25	584

The ultimate load at 28 days offers valuable insights into the performance of concrete mixes, comparing conventional reinforcement with ferrocement reinforcement mixes, along with a 10% replacement of SF. The results demonstrate that ferrocement, when applied as a coating to the test specimens with a 10% replacement of SF (MR10), achieved higher strength compared to conventional concrete. Specifically, MR10 attained a maximum ultimate load of 1350 kN, surpassing the conventional reinforcement's 613.32 kN. These findings suggest that incorporating ferrocement in test specimens enhances strength and cracking efficiency. The table 3 presents the ultimate load results for further reference.

Fig. 5. Ultimate load of retrofitting

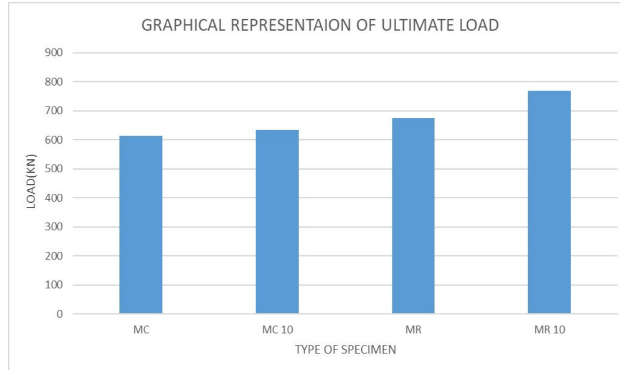

Fig. 6. Graph of ultimate load

The graph shows that the ultimate loading capacity of mix of reinforcement with 10% replacement of silica fume have maximum load bearing capacity than the conventional.

The displacement ductility at 28 days offers valuable insights into the performance of concrete mixes, comparing conventional reinforcement with ferrocement reinforcement mixes, alongside a 10% replacement of SF. The results reveal that ferrocement, when applied as a coating to the test specimen with a 10% replacement of SF (MR10), demonstrates superior ductility compared to conventional concrete. Specifically, MR10 exhibits a maximum displacement ductility of 5.2, surpassing the conventional reinforcement's 3.365. These findings indicate that incorporating ferrocement with SF replacement in test specimens enhances ductile properties. The provided table presents detailed displacement ductility results for further analysis and reference.

The first crack load at 28 days provides valuable insights into the performance of concrete mixes, particularly in comparing conventional reinforcement with ferrocement reinforcement mixes, alongside a 10% replacement of SF. The results indicate that ferrocement, when applied as a coating to the test specimen with a 10% replacement of SF (MR10), achieves superior cracking efficiency compared to conventional concrete. Specifically, MR10 demonstrates a maximum first crack load of 295 kN, surpassing the conventional reinforcement's 110 kN. These findings suggest that incorporating ferrocement in test specimens enhances both strength and cracking efficiency. The provided table presents detailed first crack load results for further analysis and reference. The figure 7 below shows the first crack load.

Fig. 7. First crack load

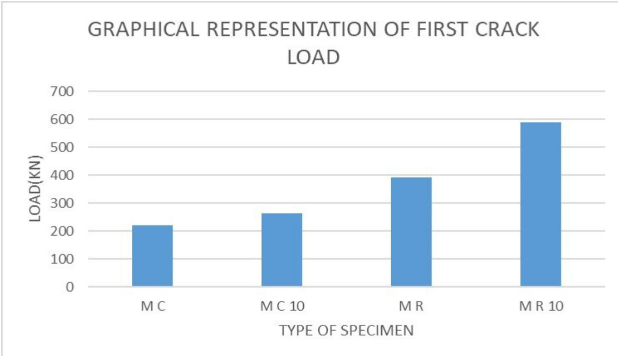

Fig. 8. Graph of first crack load

B. Energy Absorption Capacity

The energy absorption capacity at 28 days offers valuable insights into the performance of concrete mixes, comparing conventional reinforcement with ferrocement reinforcement mixes, alongside a 10% replacement of SF. The results indicate that ferrocement, when applied as a coating to the test specimen with a 10% replacement of SF (MR10), achieves the maximum energy absorption capacity compared to conventional concrete. Specifically, MR10 exhibits a higher energy absorption capacity than the conventional reinforcement. These findings suggest that incorporating ferrocement with SF replacement in test specimens accelerates the energy level.

8. Crack Pattern

Crack pattern for the test specimen as follows,

M C: On 3 specimen of M C, Crushing and buckling on the two specimens on the bottom and top side. And on the other specimen the crushing only at the top of the specimen.

M C 10: Similar to M C, the crushing and buckling occurred at all side of the one specimen, and on other specimen the buckling occurred from the end side of the specimen.

M R: Crushing and spalling occurred at all side of the specimen.

M R 10: First, all the specimen occurred crack at the top side of the specimen. And by applying the maximum load the crushing and spalling occurred slowly to inside of the specimen. but it doesn't fully crushed.

Fig. 9. Cracking pattern for retrofitting and conventional

9. Deflection Result

The energy absorption capacity is more the retrofitting than the conventional concrete mix. By analysing the graph, When the yielding point increases the relative density become maximum due to increase in linear relation.

The load deflection curve of specimen is shown in the figure below. It is clear that the retrofitted specimen with 10% replacement of Silica fume is sudden energy absorption at minimum load.

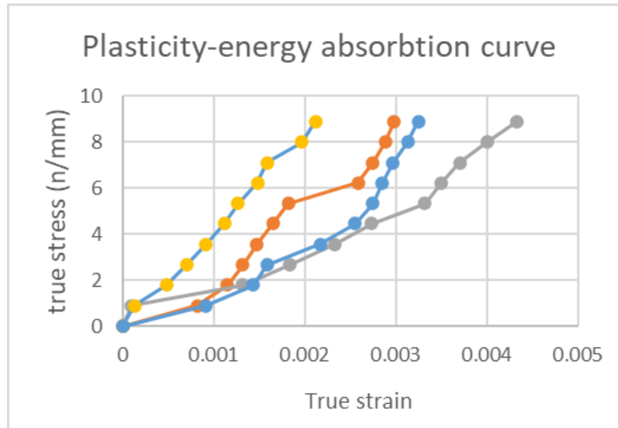

Fig. 10. Plastic-energy absorption capacity

10. Conclusion

Ferrocement with 10% replacement of silica fume improves the ultimate load bearing capacity, displacement, ductility, first crack load, energy absorption capacity. Strengthening retrofitting through the use of short columns has demonstrated remarkable efficacy, underscored by the substantial improvements in ultimate load capacity, displacement ductility, and plastic absorption capacity. The findings of this study validate the viability and effectiveness of short columns as a means to enhance structural resilience and mitigate the risks associated with seismic events or other forms of structural stress. By bolstering these critical structural parameters, short columns not only fortify the existing infrastructure but also pave the way for safer, more sustainable built environments. As we continue to confront the challenges posed by natural disasters and aging infrastructure, the adoption of such innovative retrofitting techniques stands as a pivotal step towards ensuring the longevity and safety of our built environment.

References

[1] Desayi, P Kumar, N Nel -kholy S, "A Strength and Behaviour of Ferrocement in shear" (1992).
[2] Purnachandra Saha, Tribikram Mohanty, "An experimental study on behaviour of ferrocement" (2007).
[3] T. Chandrasekhar Rao, T. D. Gunneswara Rao, "An appraisal of the shear resistance of ferrocement elements" (2006).
[4] Taha A. El-Sayed, Abeer M. Erfan, "Improving shear strength of beams using ferrocement composite" (2018)
[5] Y. Shaheena, F. Aboul-Ella, B. Eltaly and M. Kameel, "Structural Performance of Ferrocement Tanks under Pressure Loads" (2016).
[6] Amudhavalli, N. K. & Mathew, J., "Effect of silica fume on strength and durability parameters of concrete." (2012).

[7] Kumar, R., Dhaka, J., “Review paper on partial replacement of cement with silica fume and its effect on concrete properties.” (2016).
[8] Pradhan, D & Dutta, D. “Effects of Silica Fume in Conventional Concrete.” (2013).
[9] Ajileye, E.V. “Investigations on Micro silica (Silica Fume) As Partial Cement Replacement in Concrete.” (2012).
[10] Sasikumar, A. “Experimental Investigation on Properties of Silica Fumes as a Partial Replacement of Cement.” (2016).
[11] Abdullah K.M, Hussein W, ZakariaF, Muhammad R, Abdul Hamid Z., “A potential partial replacement of silica fume.” (2006).
[12] Aitcin, P. C. Hershey, P.A. and Pinsonneault, “Effect of the addition of condensed silica fume effect on the compressive strength of mortars and concrete.” (1981).
[13] Bhanja s, Sengupta B, “Optimum silica fume content and its mode of action on concrete ACI Materials” (2003).
[14] Perumal, K., Sundararajan R, “Effect of partial replacement of cement with silica fume on the strength and durability characteristics of High-performance concrete.” (2004).
[15] Cohen M.D, Bentur, “A Durability of Portland Cement-Silica Fume Pastes in Magnesium Sulphate Attack and Sodium Sulphate Solution.” (1988).