NUMERICAL AND PARAMETRIC STUDY ON STRENGTH AND BEHAVIOUR OF ECC COLUMNS UNDER CYCLIC LOADING

LITERATURE REVIEW

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Abstract - The term "engineered cementitious composite" (ECC) refers to a class of cementitious compositions with strain-hardening and crack-control properties. It's a cement-based substance with polyvinyl alcohol (PVA) or polyethylene (PE) fibres used as reinforcing elements. Concrete replacement with ECC can prevent cracking or postpone the spread of cracks, as well as durability issues connected to concrete brittleness. When compared to regular concrete, ECC prevents severe concrete damage in crucial areas by creating micro fractures and has a better bond with reinforcing. The goal of this study is to learn more about the behaviour of ECC columns that have been subjected to reverse cyclic loading. The finite element programme ANSYS 19.2 will be used to do numerical modelling of columns during this project. The experimental results are used to validate the simulated column. The ECC columns are modelled with PVA fibres and fly ash instead of cement. In terms of hysteresis curve, skeleton curve, stiffness degradation, ductility, and energy dissipation, the created finite element model is used to simulate the behaviour of ECC columns. The effect of various parameters will next be investigated using a detailed parametric analysis. The compressive strength of ECC, PVA fibre content by volume, constant axial load applied, and longitudinal and transverse reinforcement ratio are the main characteristics examined.

1.INTRODUCTION

Engineered cementitious composite (ECC) is an ordinary Portland cement-based composite with ultra-ductile fiber reinforced. Strain hardening cement-based composite is another name for them. The acute tensile strain capacity of ECC exceeds that of regular concrete by a significant margin.

The goal of ECC is to establish synergistic interactions between fibre, matrix, and interface in order to promote tensile ductility by forming closely spaced numerous micro fractures with minimal fibre content. Glass, carbon, synthetics, and natural fibres are used as reinforcement in ECC, which is a high-performance fibre reinforced concrete. To ensure that the polymer fibres are distributed evenly throughout the matrix, coarse particles are removed. This aids in the hardened material's high ductility. ECC is part of the HPFRCC (High-Performance Fibre Reinforced Cementitious Composite) family, which is a type of ultra-ductile short discrete fibre reinforced cementitious composite created for such potentially difficult applications. ECC is a type of ultra-ductile fibre reinforced cementitious composite designed for high-volume, low-cost construction applications. ECC has evolved significantly in terms of both material development and, as a result, the spectrum of emerging applications since its launch a decade ago. ECC is a type of HPFRCC that is prepared by achieving the critical fibre volume fraction for a certain type of fibre that satisfies the two important qualities of ECC that distinguish it from other HPFRCCs, namely ultra-high ductility and tight fracture width control. The crack width of ECC remains below 100m even under a strain of 4-5 percent. A narrow crack width indicates a significant increase in structural durability. The micromechanical based design technique is frequently used to obtain these qualities. To achieve the strain hardening behaviour, micromechanical parameters related to fibre, matrix, and interface are integrated to satisfy the first crack stress criterion and steady state cracking criterion. In addition, the fibres are anticipated to support loads and are thus integral to the structural response. This is in stark contrast to FRC, where the fibres can only function to reduce shrinkage cracking and cannot be expected to support any externally applied stress.

Columns and other major structural elements in earthquake-resistant structures should be ductile. Under cyclic loads, conventional concrete cracks and crushes, resulting in low tensile strength and ductility. Fibres in the concrete matrix change the brittle reaction of the material. Concrete replacement with ECC can prevent cracking or postpone the spread of cracks, as well as durability issues connected to concrete brittleness. The most important mechanical property difference between ECC and fibre reinforced concrete (FRC) is that after first breaking, ECC strain-hardens rather than tension-softens. As fibres are pulled out or ruptured in FRC, the original crack continues to open, reducing the stress-carrying capacity. The first cracking in ECC is followed by a rise in stress as the strain increases. ECC possess increased tensile ductility with minimum fibre content, by development of multiple micro cracks.

1.2 Applications

In building, transportation, and water infrastructure

-as repair material

-as retrofitting material

-as new construction material

In a number of projects, ECC was used as a field repair material.

In bridges with adjacent box beams and voided slabs, ECC has been used as shear keys.

In Hiroshima, Japan, ECC was used to repair the Mitaka dam. ECC was sprayed onto the upstream dam surface in a 20mm layer.

ECC was used to fix a concrete earth retaining wall. The need to prevent reflective cracking from the substrate concrete through the repair layer necessitated the use of ECC.

In the United States, ECC was used to restore a piece of a deteriorating bridge deck.

1.1 Physical properties of ECC

Physical properties of ECC	
Compressivestrength	20-95MPa
First crack strength	3-7MPa
Ultimate tensile strength	4-12MPa
Ultimate tensile strain	1-8%
Young's Modulus	18-34 GPa
Flexural Strength	10-30 MPa
Density	0.95-2.3

Table -1 Physical properties of ECC(Li et al., (2007))

2. LITERATURE REVIEW

Extensive research is being out to examine the qualities of ECC. This chapter provides a rapid overview of previous research in the subject of engineered cementitious composite flexural and other mechanical properties.

1.2 Review of literature

Wu et al., (2017) investigated the seismic behaviour of steel Reinforced ECC columns under constant axial loading and reversed cyclic lateral loading. On Reinforced Engineered Cementitious Composite columns, as well as one control reinforced concrete (RC) short column, various shear span-to-depth ratios, axial load levels, and transverse reinforcement ratios were investigated. On test specimens, constant axial stress and reversed cyclic lateral loading were applied. RECC columns with smaller shear span to depth columns and short Reinforced Concrete columns collapse by shear, according to test results. In terms of ductility, energy dissipation capacity, and damage tolerance, RECC columns with a higher shear span to depth ratio outperform RC columns. RECC column without stirrups likewise failed in a flexure-dominated way. The test results validated shear strength expressions and theoretical flexural strength of RECC columns.

Cho et al. (2019) investigated the seismic capability of reinforced concrete (RC) composite columns made of a high-ductile fibre cementitious composite (HDFC). They looked at how to make earthquake-resistant reinforced-concrete columns using a high-ductile fibre cementitious composite. For seismic evaluations, four column specimens were produced and subjected to a series of cyclic load tests. In both RC and HDFC columns, bending and shear cracks in the flexural critical region were reduced, and seismic performance was improved. Enhanced the column's flexural capacity under cyclic lateral loads while maintaining axial load security, Column with precast HDFC box demonstrated improved overall lateral load-carrying and deformation capacities when compared to RC column.

Li et al., (2017) presents a study on cyclic behaviour of damaged reinforced concrete columns repaired with high-performance fibre-reinforced cementitious composite. The study's major goal is to develop an effective and simple-to-apply restoration approach for RC columns that have been damaged by earthquakes. Under amplitude-increasing lateral stresses and a constant axial load, four columns were prepared and tested to 85 percent of their load-carrying capability. The load-carrying capacity and ductility of original columns may be less than that of rehabilitated columns. The cyclic performance of repaired columns was improved when they were subjected to axial loads. Increased repair height beyond the plastic hinge zone enhanced load-carrying capacity and ductility marginally. In order to get the best performance-to-cost ratio, the repair height of a high-performance fibre-reinforced cementitious composite should be 1.5 times the depth or width of the damaged column.

Pedram Zohrevand, and Amir Mirmiran., (2012) conducted a research on cyclic behaviour of hybrid columns made from ultra-high performance concrete and fibre reinforced polymer. Two specimens were steel-reinforced: one with conventional concrete (RC) and the other with Reinforced ultra-high performance concrete within twice the plastic hinge length and traditional concrete for the rest of the column length (RUHPC). The other two had FRP tubes, one stuffed with traditional concrete (CFFT) and the other (UHPCFFT) stuffed with UHPC for the first half of the column length and traditional concrete for the rest. Each column was evaluated as a cantilever under a constant axial load as well as reverse cyclic lateral stresses that were delivered incrementally in displacement control. Each column was tested as a cantilever with a constant axial load and reverse cyclic lateral forces applied incrementally in displacement control. Internally reinforced tubed specimens demonstrated the same flexural strength and ductility as steel-reinforced equivalents. UHP-CFFT has much better flexural strength and initial stiffness than RC, as well as lower residual drift and similar energy dissipation. Because ultra-high performance concrete has a higher compressive strength, it has a lower confinement ratio and reinforcing index, which prevents it from attaining its full dilatation and crushing capacity

Shaikh Paiz Uddin Ahmed et al. (2007) developed an analytical model for hybrid fibre-ECC tensile strain hardening and multiple cracking behaviour. The ECC model for hybrid fibres can forecast first crack strength and supreme bridging strength. The model can predict the minimal volume percentage of fibres necessary to demonstrate strain-hardening and multiple-cracking behaviour in uniaxial tension.

Experiments with hybrid fibre ECC specimens were also used to validate the concept. An additional parametric analysis is undertaken using this model to investigate the effects of fibre length, diameter, and interfacial bond strength on the initial crack strength, ultimate bridging strength, and critical volume percentage of fibres. The findings of the experiments were found to be in good agreement with the ultimate bridging strength. However, the model is found to overestimate the strength of the first crack. The critical volume percentage of fibres in hybrid fibre composites is frequently optimised by choosing the right fibre length, diameter, and interfacial bond strength. In comparison to high modulus fibres, low modulus fibres have a more pronounced effect on the strain-hardening and multiple-cracking behaviors of hybrid fibre composites.

Bora Gencturk and Amr S. Elnashai (2012) studied ECC architectures using numerical modelling and analysis. A macroscopic cyclic constitutive model for ECC materials at the stress-strain level is built based on the material's behaviour under various loading regimes. Before being incorporated into fiber-based finite element analysis tools for structural simulation, the model is evaluated at the stress-strain level. The results of ECC member simulations under cyclic and static time history loading were compared to experimental data for structural model validation. A parametric analysis is carried out at the member level to investigate the impact of ECC ductility and tensile strength on structural level response parameters such as stiffness, strength, ductility, and energy dissipation capacity.

Yuan et al., (2018) investigated about behaviour of hybrid steel and FRP- reinforced concrete-ECC composite columns under reversed cyclic loading. A new form of hybrid steel-FRP-reinforced concrete-ECC composite column was proposed during the research, with ECC applied to the plastic hinge area and tested under reversed cyclic loading. A comparison test was also done on a hybrid steel-FRP-reinforced concrete column. The effect of matrix type within the plastic hinge region on the columns' failure mode, crack pattern, ultimate strength, ductility, and energy dissipation capacity was studied. By replacing concrete with ECC at the plastic hinge zone, local buckling of Frp bars can be successfully avoided, and the column's strength and ductility can be improved. The load carrying capability, ductility, and energy dissipation capacity of the hybrid steel-FRP reinforced column enhanced when ECC was replaced with concrete in the plastic hinge region. The anchoring system efficiently prevents bond-slip failure between GFRP bars and concrete. With ECC, a more stable confinement on the GFRP bars can be achieved than with concrete.

Xu et al., (2012) studied on mechanical behaviour of ECC and ECC/RC composite columns under reversed cyclic loading. The mechanical behaviour of ECC/RC composite columns was studied in this research. Within the column bottom, concrete is frequently replaced with ECC to create an ECC/RC composite column. The experimental characteristics evaluated included material composition, transverse reinforcement ratio, and axial load level. On nine scaled columns, experimental results from reversed cyclic load tests were shown. The ECC and ECC/RC composite columns exhibit greater energy dissipation capacity, ductility, and stiffness degradation than RC columns, according to the results. The ductility of the ECC/RC composite column is harmed by the increase in axial load, while the load capacity and structural integrity are significantly improved. Due of ECC's strong shear strength, the number of stirrups in ECC and ECC/RC composite columns is frequently reduced.

Khlef et al. (2019) investigated the stress and cyclic behaviour of high-performance fiber-reinforced cementitious composites (HPFRCC). Polyvinyl alcohol (PVA) fibres and twisted steel fibres are utilised to make 10 different mixtures for the experimental programme, with percentages of 1 percent, 2 percent, and 3 percent by volume of the mixture. The response of HPFRCCs was evaluated using a testing approach that included monotonic tension loading, cyclic tension-only loading, and cyclic tension-compression loading. With the use of test data, a benchmark for cyclic constitutive curves for mono and hybrid HPFRCC mixtures was established. In comparison to mono mixes, hybrid mixtures had a better overall performance. By obtaining stronger toughness, higher energy absorption capacity during hardening, higher energy absorption capacity during softening, and mild toughness reduction under cyclic loading, hybrid mixtures outperformed PVA and steel mono mixtures.

Antony Salamy N & Gayathiri S., (2017) investigates on comparative study on ECC and RCC beam column connections for enhancing seismic resistance. A G+4 commercial building in a high seismicity zone was used as a model. The essential beam column connection was picked from that structure. ANSYS software was used to analyse this specimen by modifying the ECC and changing the arrangement of transverse reinforcements, their number, and thus the materials within the plastic zone of the connection. The comparison employed ultimate load, ultimate displacement, and strain energy capacity of control concrete and ECC as parameters. The application of ECC has given the specimens a stronger ability to resist and survive the cyclic stress, based on the ANSYS modelling and analysis performed on the beam column junction. Also, make the concrete malleable in the event of a seismic event. Because of the influence of polyethylene microfibers in concrete, it has good strength and ductility, as well as the ability to self-heal and manage cracks. In beam-column joints, engineered cementitious composites concrete materials are frequently used.

Nehdi et al., (2019) conducted experimental and numerical study of ECC with Strain recovery under impact loading. The impact behaviour of the composite was numerically simulated, and the model predictions matched the experimental observations well. In comparison to control mono-PVA specimens, integrating SMA fibres into the composite resulted in higher impact resistance, as evidenced by numerical and experimental tests. Due to the shape memory effect, heat treatment prompted SMA fibres to apply local prestress on the composite's matrix, increasing energy absorption capacity despite PVA fibre breakage during the heating process. The addition of SMA fibre to the ECC composite improved its tensile characteristics and impact resistance. With the inclusion of SMA fibre, the impact penetration depth tended to decrease With the inclusion of

SMA fibre, the impact penetration depth tended to decrease. The heated hybrid composite's energy absorption capability was found to be significantly higher than that of its non-heated counterpart.

Billington et al., (2004) investigated on cyclic response of unbounded post tensioned precast columns with ductile fibre-reinforced concrete (DFRCC). During this project, a precast segmental concrete bridge pier structure was examined for usage in seismic zones. The suggested approach joins the precast segments with unbounded post tensioning (UBPT), with the option of using a ductile fiber- reinforced cement-based composite within the precast segments at probable plastic hinging zones. The UBPT is expected to result in minimum residual displacements and hysteretic energy dissipation. The DFRCC material should be able to dissipate hysteretic energy while also being damage resistant.. Small-scale experiments on cantilever columns were carried out using the proposed system. The fabric used in the plastic hinging region section, as well as the depth to which that segment was implanted in the column base, were the two key variables. Up to drift values of 3-6 percent, DFRCC allowed the system to discharge more hysteretic energy than conventional concrete. When subjected to high cyclic tensile compressive loads, ductile FRCC held up better than reinforced concrete. The hysteretic energy dissipation and extent of micro cracking in the FRCC were controlled by the bottom segment embedment depth.

Manvi et al., (2017) done a search on Evaluation of Mechanical Properties of Hybrid Engineered Cementitious Composite (HECC). This work focuses on the research of Hybrid Engineered Cementitious Composite, a new type of High-Performance Fibre Reinforced Cementitious Composite that incorporates steel and polypropylene fibres to create a hybrid cementitious composite. The combination of steel and polypropylene fibres improves the characteristics of each individual fibre and produces a synergistic response. The mechanical properties (compressive strength, splitting tensile strength, and flexure strength) have improved thanks to the hybridization of steel and polypropylene fibres.

Hocine siad et al., (2017) presented the utilisation of recycled glass powder to enhance the performance of high-volume fly ash engineered cementitious composite. The purpose of this article was to investigate the inclusion of recycled glass powder into HVFA- ECC. Compressive strength, chloride ion resistance, electrical resistivity, self-healing, final strength recovery rate, and physical attributes were all investigated. It was discovered that incorporating recycled glass powder into HVFA- ECC increases the self-healing, chemical, physical, and other mechanical capabilities of the material.

Yu et al., (2018) investigated on the direct tensile properties of Engineered Cementitious Composite. This comprehensive overview summarizes the essential information on parameters that impact the tensile properties of ECC, specifically fibre qualities, specimen size and geometry, and strain rate. It has been determined that the fibre characteristics of ECC have a significant impact on its tensile performance. In tensile tests, there is a size and geometry influence that needs to be investigated further. The tensile characteristics of ECC vary noticeably when subjected to high rates of loading. For a wider application of ECC material, the durability of tensile qualities should be explored further.

3. CONCLUSIONS

Detailed literature survey give us a theoretical knowledge of ECC columns under cyclic loading. From these it was evident that replacement of conventional concrete with ECC helps to increase ductility, tensile strength etc..

REFERENCES

[1] 1 **Chang Wu, Zuanfeng Pan, R. K. L. Su, C. K. Y. Leung & Shaoping Meng** (2017) Seismic behavior of steel reinforced ECC columns under constant axial loading and reversed cyclic lateral loading, *Materials and Structures (2017) 50:78*

[2] **Chao Li, Hong Hao & Kaiming Bi** (2017) Numerical study on the seismic performance of precast segmental concrete columns under cyclic loading, *Engineering Structures 148 (2017),* pp 373-386

[3] **Fang Yuan , Liping Chen, Mengcheng Chen & Kaicheng Xu** (2018) Behaviour of Hybrid Steel and FRP-Reinforced Concrete-ECC Composite Columns under Reversed Cyclic Loading, Sensors 2018, 18, 4231; doi:10.3390/sl 812423l

[4] **Gregor Fischer and Victor C. Li (2013)** Deformation Behaviour of Fibre-Reinforced Polymer Reinforced Engineered Cementitious Composite (ECC) Flexural Members under Reversed Cyclic Loading Conditions, *AC! Structural Journal,* V. 100, No. **1.**

[5] **Bora Gencturk & Amr S. Elnashai** (2013) Numerical modelling and analysis of ECC structures, *Materials and Structures (2013) 46:663-682*

[6] **Ali Khodayaria, Ulrich Hirn, Aart W. Van Vuure & David Seveno** (2020) Inverse rule of mixtures at the nanoscale: Prediction of elastic properties of cellulose nanofibrils, *Composites Part A 138 (2020) 106046,* ELSEVIER

[7]

[8] **Antony Salomy N** & **Gayathiri S** (2017) Comparative Study on ECC and RCC Beam Column Connections for Enhancing Seismic Resistance, *International Journal*

of ChemTech Research CODEN (USA): IJCRGG, ISSN: 0974-4290, ISSN(Online):2455-9555 Vol.10 No.14, pp 58-66.

[9] **Zuanfeng Pan, Yazhi Zhu, Zhi Qiao & Shaoping Meng** (2020) Seismic behavior of composite columns with steel reinforced ECC permanent formwork and infilled concrete, *Engineering Structures*, Volume 212, **1** June 2020, 110541 ELSEVIER