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A Review On- Fiber-Section Model with an Exact Shear Strain Profile for Two- Dimensional RC Frame Structures

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ABSTRACT: A fiber-section model for nonlinear analysis of shear-critical reinforced concrete frames is developed. The model incorporates a new procedure for the computation of an exact shear strain profile and corresponding shear stress distribution over the cross section. Longitudinal axial strains are evaluated based on the plane section assumption, whereas transverse strains are determined from equilibrium in the vertical direction, following classical beam assumptions. Axial-shear interaction at the fiber level is based on a smeared-crack orthotropic constitutive model, which uses equivalent uniaxial material models for concrete and steel in the crack and reinforcement directions, respectively. Shear strain components at the crack, arising from deviations between principal and crack directions, are related to shear stresses by means of a shear stiffness term that fully satisfies compatibility and equilibrium conditions. The procedure was implemented into a force based element and applied to monotonic and cyclic analysis of lightly reinforced beams, shear-critical frames, and columns.

KEYWORDS: Reinforced concrete; Finite-element analysis; Frame elements; Axial-shear interaction; Concrete and masonry structures.

I. INTRODUCTION

Extensive experimental and analytical effort has been devoted to investigate the response of RC members under combined axial and shear stresses in the last 50 years. This allowed for the development of refined finite-element models capable of predicting the global force-displacement response up to collapse, as well as local response parameters such as strains, crack widths, and crack pat-terns. However, their general application to framed structures is cumbersome and time consuming, and hence, substantial effort is being directed toward improving existing frame elements, usually based on the plane section assumption and uniaxial constitutive laws, in order to account for multiaxial loading conditions while keeping an efficient and simple formulation. [1]

Moreover, the ultimate displacement predicted with the flexure fiber element was 65 mm, 2.8 times the experimental one, thus significantly overestimating the ductility capacity of the member. Note that this fact poses an important limitation to performance-based engineering practices, which strongly rely on accurate deformation-based predictions. The results from the flexure-shear element are in better agreement with the experiment because axial-shear interaction is taken into account (Fig. 1).]This is accomplished using the Timoshenko beam theory combined with advanced two-dimensional material models for cracked concrete. However, the classical Timoshenko beam theory predicts a uniform shear strain distribution over the cross section, violating the principles of equilibrium among section fibers. [2] A novel sectional algorithm is proposed herein based on an exact evaluation of the shear strain and stress profiles at each element integration point. [3]

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The ex-act profile is derived using an averaged form of inter fiber equilibrium over the cross section and piecewise linear interpolation of the shear strain distribution, following standard finite-element approximation techniques. [4] The formulation was implemented into a two-dimensional force-based fiber element with a smeared-crack, fixed-crack cyclic constitutive model. Verification examples on shear-critical beams, frames, and columns are provided at the end. [5]

A promising fiber-based frame element for axial-shear interaction requires (1) an accurate multiaxial constitutive model; and plausible section and beam kinematic assumptions. Vecchio and Collins (1988) introduced axial-shear interaction at the fiber level based on a dual-section analysis, whereby shear stresses over the section were calculated from the differences between axial stresses at two consecutive sections separated by $h/6$ (where h is the depth of the section). The selection of $h/6$ was more driven by numerical issues of stability and convergence rather than sound physical background. Moreover, the implementation of this procedure in a beam-column finite element is not straightforward

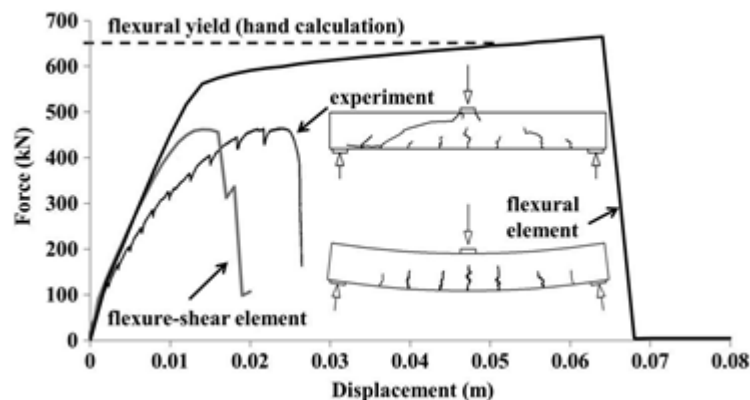


Fig. 1. Experimental and analytical responses for a shear-critical beam

Stability and convergence was improved by Bentz (2000), who suggested a local procedure, such that shear stresses were obtained from longitudinal gradients of deformations at one single section. However, this procedure was limited to monotonic sectional analysis. Both references used a two-dimensional constitutive model, namely the modified compression field theory (MCFT) (Vecchio and Collins 1986), assuming that plane sections remain plane and there is a full bond between reinforcement and concrete.

1.1 Objectives

Our aim to find the A fiber-section model for nonlinear analysis of shear-critical reinforced concrete frames is developed. The model incorporates a new procedure for the computation of an exact shear strain profile and corresponding shear stress distribution over the cross section. Longitudinal axial strains are evaluated based on the plane section assumption, whereas transverse strains are determined from equilibrium in the vertical direction, following classical beam assumptions. Axial-shear interaction at the fiber level is based on a smeared-crack orthotropic constitutive model, which uses equivalent uniaxial material models for concrete and steel in the crack and reinforcement directions, respectively.

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1.2 Scope of the Project Work

The scope of our project is to evaluate of an exact shear strain profile was satisfactorily implemented within a force-based, fiber-based frame element for monotonic and cyclic analysis of shear-critical RC structures.

Conceptually speaking, the element is superior to elements with fixed shear strain profiles, such as those with constant or parabolic patterns. However, the element kinematics still rely on the Timoshenko beam theory, i.e., plane section assumption and no section distortion or warping, resulting in kinematic incompatibility between fiber deformations and element displacements.

1.3 Methodology

The present work aims at bridging the gap between the simplified Timoshenko elements based on fixed shear strain patterns and the more complex higher-order formulations. The possibility of an exact shear strain profile is explored at the sectional level while maintaining the plane section assumption for longitudinal strains. The rationale behind this approach is that Bentz (2000), among others, demonstrated that axial-shear interaction in beams and columns can be well-captured assuming that plane sections remain plane. Moreover, Bairan and Mari (2007) and Ranzo and Petrangeli (1998) pointed out the importance of an accurate material stress distribution for a competitive beam element when compared to re-fined 3D finite-element models. Details on the proposed formulation are presented in the following sections.

II. LITERATURE REVIEW

1. FIBER ORIENTATION FACTOR ON RECTANGULAR CROSS-SECTION IN CONCRETE MEMBERS

FROM THIS PAPER I REFER-

In order to predict the post-cracking tensile behavior of fiber reinforced concrete, it is necessary to evaluate the fiber orientation factor which indicates the number of fibers bridging a crack. For investigation of fiber orientation factor on a rectangular section, in this paper, dog-bone fiber reinforced concrete specimens were prepared with the variables of concrete compressive strength, rectangular cross-section size, fiber type, and fiber volumetric ratio. After direct tension tests, the fiber orientation factor could be evaluated through counting the number of fibers on a crack. From the test results, it was investigated that the fiber orientation factor was larger than 0.5 which is generally adopted for large members, as fibers distribution is affected by the specimen size. For rational prediction of the fiber orientation factor on a rectangular concrete section, a simple model was derived from the Diverse Embedment Model (DEM), which is a rigorous model to predict the tensile behavior of steel fiber reinforced concrete. From the comparison of the measured data and the predicted values, it was found that the actual fiber orientation factor was well predicted by the proposed model.

2. UNIVERSAL DESIGN MODEL FOR REINFORCED CONCRETE SECTIONS IN FLEXURE

FROM THIS PAPER I REFER

The development of a design model for steel reinforced concrete section is presented in this paper. The required area of reinforcement steel in the concrete can be easily found using the model. Various geometrical cross-sections including solid and hollow rectangular and non-regular sections can be treated by the method for both elastic and plastic designs. The only requirements in the method are the yield stresses of Steel and Concrete, and the section modulus of the cross section chosen. Results from the proposed design method are comparable to those of various codes and standards in the case of reinforced concrete and so validate the method. Some new results are established for cross sections that cannot be easily handled by the present codes and standards.

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3. FEASIBILITY OF USING HIGH-PERFORMANCE STEEL FIBRE REINFORCED CONCRETE FOR SIMPLIFYING REINFORCEMENT DETAILS OF CRITICAL MEMBERS

FROM THIS PAPER I REFER

This paper addresses the effects of hooked-end steel fibre contents on the mechanical properties of high-performance concrete (HPC) and investigates the feasibility of utilizing steel fibres to simplify the complicated reinforcement detailing of critical HPC members under high shear stress. Mechanical properties of HPCs with specified compressive strength of 60 and 100MPa include the flow, air content, compressive strength, and flexural strength. The effectiveness of 1.50% steel fibre content on the shear behaviour of diagonally reinforced concrete coupling beam without additional transverse reinforcement was investigated to alleviate complex reinforcing details for the full section confinement of diagonal bar groups. The test results revealed the incorporation of steel fibres significantly affected the mechanical properties of the HPCs. For diagonally reinforced coupling beam(SFRCCB)without additional transverse reinforcement, the addition of 1.5% steel fibre content into 60MPa HPC coupling beam provides similar cracking and structural behaviour compared to those of diagonally reinforced coupling beam (CCB) with full section confinement details. However, the ductility of SFRCCB was less than that of CCB. It is recommended that both stirrups and steel fibre should be used for fully confining the diagonal bar groups of coupling beams to achieve the ductile behaviour.

4. M.B.S ALFERJANI “USE OF CARBON FIBER REINFORCED POLYMER LAMINATE FOR STRENGTHENING REINFORCED CONCRETE BEAMS IN SHEAR: A REVIEW”

FROM THIS PAPER I REFER

The use of Fiber Reinforced Polymer (FRP) is becoming a widely accepted solution for repairing and strengthening ageing in the field of civil engineering around the world. Several researches have been carried out on reinforced concrete beams strengthened with fiber reinforced polymer composite. Some of the works were focused on shear strengthening compared with flexural strengthening that had the largest share. This paper reviews 10 articles on carbon fiber reinforced polymer strengthened reinforced concrete beams. Finally, this paper attempts to address an important practical issue that is encountered in shear strengthening of beams with carbon fibre reinforced polymer laminate. This paper also proposes a simple method of applying fibre reinforced polymer for strengthening the beam with carbon fibre reinforced polymer.

5. A REVIEW ON PERFORMANCE OF COIR FIBER REINFORCED SAND

FROM THIS PAPER I REFER

Reinforced earth is a composite material, a combination of soil and reinforcement duly placed to bear the tensile stresses developed and also to improve the resistance of soil in the direction of maximum stress. The majority of currently published literature about randomly oriented fiber reinforcement deals with the reinforcement of cohesion less or granular soils.. Availability, economical benefits, easy to work and rapid to perform; and feasibility of using in all weather conditions are the general advantages of short fiber composite soils. The technical benefits of using fibers in soil reinforcement include: preventing the formation of the tensile cracks, increasing hydraulic conductivity and liquefaction strength, reducing the thermal conductivity and weight of building materials, restraining the swelling tendency of expansive soils; and decreasing the soil brittleness. It can be concluded that the increase in strength and stiffness was considered to be a function of Fiber characteristics like aspect ratio, skin friction, weight fraction modulus of elasticity, shape, particle size and gradation of sand and confining stress condition

6. IMPROVEMENT OF TORSIONAL RESISTANCE IN ULTRA-HIGH PERFORMANCE FIBRE REINFORCED CONCRETE BEAMS

FROM THIS PAPER I REFER

Ultra-high performance fibre reinforced concrete (UHPFRC) is an especial kind of concrete which has high compressive and relatively high tensile strength. However, this concrete has a high value of brittleness index in comparison with fibrous normal and high strength concrete. Therefore, cracking in this type of concrete could be

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occurred and propagated suddenly. The torsional resistance in UHPFRC beams is provided by concrete prior to cracking and reinforcements plus fibres at post cracking stages because the concrete carries tensile stress in the pre-crack stage and reinforcements with fibres carry tensile stress in the post cracking stage. The contribution of the concrete, fibre and reinforcements is influenced by using of UHPFRC. The torsional resistance provided by fibres is improved due to high volume fraction ratio in the concrete. Furthermore, the amount of stress in the reinforcement in post cracking stage is reduced due to thick concrete cover. The thickness of concrete cover is more, the stress in reinforcements are less. Therefore, the contribution of reinforcements to resist torsion after cracking reduced [1].

7. AISHWARYA R “A REVIEW ON SHEAR STRENGTHENING OF RC BEAMS USING EMBEDDED THROUGH SECTION (ETS) TECHNIQUE”

FROM THIS PAPER I REFER

The Embedded Through-Section (ETS) technique is a recently developed technique for the shear strengthening of reinforced concrete (RC) beams. This technique involves drilling of holes through the beam cross section and bonding steel or fibre reinforced polymer (FRP) bars using epoxy adhesive. Strengthening techniques like external bonding of reinforcement (EBR) and near surface mounting of reinforcement (NSM) are the commonly used shear strengthening methods; however the ETS technique is an even better shear strengthening technique introduced in the recent years. This paper gives a review on the ETS shear strengthening procedure, merits of ETS technique over the conventional techniques like EBR and NSM and also the various parameters influencing the shear strength of RC beams strengthened using ETS technique

III. CONCLUSION

From the consideration of all the above points we conclude that the evaluation of an exact shear strain profile was satisfactorily implemented within a force-based, fiber-based frame element for monotonic and cyclic analysis of shear-critical RC structures. Conceptually speaking, the element is superior to elements with fixed shear strain profiles, such as those with constant or parabolic patterns. However, the element kinematics still rely on the Timoshenko beam theory, i.e., plane section assumption and no section distortion or warping, resulting in kinematic incompatibility between fiber deformations and element displacements. A number of verification examples, including shear-critical RC beams, frames, and a pier, showed relatively good agreement in terms of post-cracked stiffness, shear strength, and ultimate displacement capacity. Realistic stress and strain distributions over the section were obtained; however, further verification and comparison with experimental data is required.

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