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Strictly as per the compliance and regulations of :

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I. Introduction

Strut-and-tie modeling (STM) is an approach used to design discontinuity regions (D-regions) in reinforced and prestressed concrete structures. A STM reduces complex states of stress within a D-region of a reinforced concrete deep beam into a truss comprised of simple, uniaxial stress paths. Each uniaxial stress path is considered a member of the STM. Members of the STM subjected to tensile stresses are called ties and represent the location where reinforcement should be placed. STM members subjected to compression are called struts. The intersection points of struts and ties are called nodes. Knowing the forces acting on the boundaries of the STM, the forces in each of the truss members can be determined using basic truss theory. Strain obtained analytical by software was compared with strain recorded experimentally.

II. Computer Aided Strut-And-Tie (Cast) Analysis

A research programme was recently conducted to advance the STM for overcoming the aforementioned challenges. In addition to making the design and analysis process using the STM more efficient and transparent, the research aimed to extend the basic use of the STM from a design tool to an analysis tool that can be used for evaluating member behavior and there by making it possible to evaluate/validate/extend design code provisions (e.g. dimensioning rules and stress limits) of deep beam. By using a computer-based STM tool called CAST (computer aided strut-and-tie) was developed by Tjhin and Kuchma at the University of Illinois at Urbana-Champaign (2002). This tool is the subject of this paper. CAST facilitates the instruction activities for analysis of reinforced concrete deep beam by STM. This paper considers D-regions that can be reasonably assumed as plane (two-dimensional) structures with uniform thickness and the state of stress is predominantly plane (plane stress condition). Two point loading acting on the D-regions is limited to static monotonic, but can be extended to account for the degradation effects of repeated loading. Only strut-and-tie models that consist of unreinforced struts and non-prestressed reinforcement ties are considered. The primary failure modes of the D-regions are the yielding of ties, crushing of struts or nodal zones and diagonal splitting of struts. Failures due to reinforcement anchorage and local lateral buckling are not considered.

III. Analytical Modeling Of RC Deep Beam

The strut-and-tie model was analyzed using CAST software. Experimental and analytical deep beam model was having 0.7 m length, 0.4 m depth and 0.15 m thick. The materials properties obtained from material tests will used for concrete and reinforcing steel in the models. By doing so, the strength reduction factor ϕ was set to unity. The supports where modeled as a vertical reaction on the left support and a vertical and horizontal reaction on the right support The software's capacity prediction feature was used to estimate the capacity using the provided steel reinforcement, concrete struts and nodal zones.

Additionally, the software has a feature that allows analysis of the nodes to ensure that geometry and stress limits are not exceeded. The estimated capacity according to CAST, the failure would occur by yielding of the diagonal tie. This is desirable in STM because it allows the member to fail in a ductile manner as the reinforcing bars yield first before failure, as opposed to brittle failure of the concrete strut.

IV. Strut-and-Tie Method: Design Steps

The design process using the Strut-and-Tie Method involves steps described below. These steps

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are illustrated using the design example of a deep beam.

1. Define the boundaries of the D-Region and determine the boundary forces (the ultimate design forces) from the imposed local and sectional forces. Boundary forces include the concentrated and distributed forces acting on the D-Region boundaries. Boundary forces can also come from sectional forces (moment, shear, and axial load) at the interface of D- and B-Regions. Body forces include those resulted from D-Region self-weight or the reaction forces of any members framing into the D-Region.
2. Sketch a Strut-and-Tie Model and solve for the truss member forces.
3. Select the ordinary reinforcing steel and prestressing steel that are necessary to provide the required Tie capacity and ensure that they are properly anchored in the Nodal Zones.
4. Evaluate the dimensions of the Struts and Nodes such that the capacity of all Struts and Nodes is sufficient to carry the truss member forces.
5. Provide distributed reinforcement to ensure ductile behavior of the D-Region.

Since equilibrium of the truss with the boundary forces must be satisfied (step 2) and stresses everywhere must be below the limits (step 3 and 4), one can see that the Strut-and-Tie Method is a lower-bound (static or equilibrium) method of limit analysis.

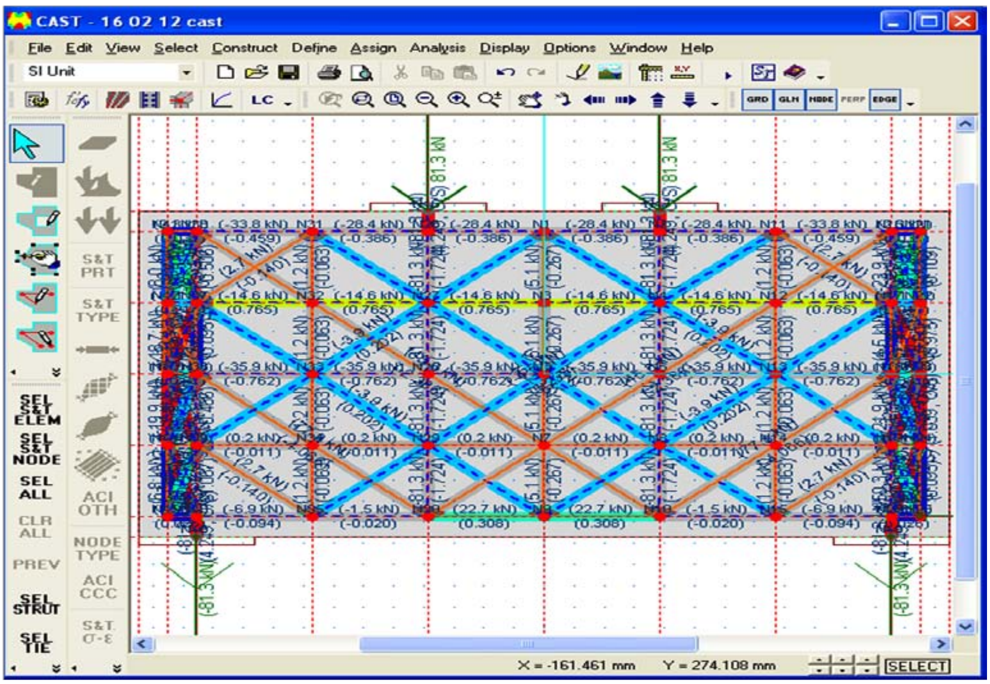


Figure 1 : Forces in members by CAST analysis

Above figure shows the forces in strut and tie developed in deep beam using CAST software similarly strain and stress are obtained in graphical as well as tabulated form.

V. Experimental Work

In experimental investigation of deep beam we have taken same size of deep beam of total length 700 mm, depth 400 mm and width 150 mm. Which were casted in concrete technology labarotaty and curring was carried out for 28 days. M25 gread of concrete were used for deep beam. For application of load we have used 1000 kN capacity hydraulic heavy testing machine. To measure deflection dial gauge where placed at central position of bottom of deep beam. to measure strain along mid span we have used strain gauge at equally spacing from top to bottom.

Figure 2 : Test setup for Deep beam

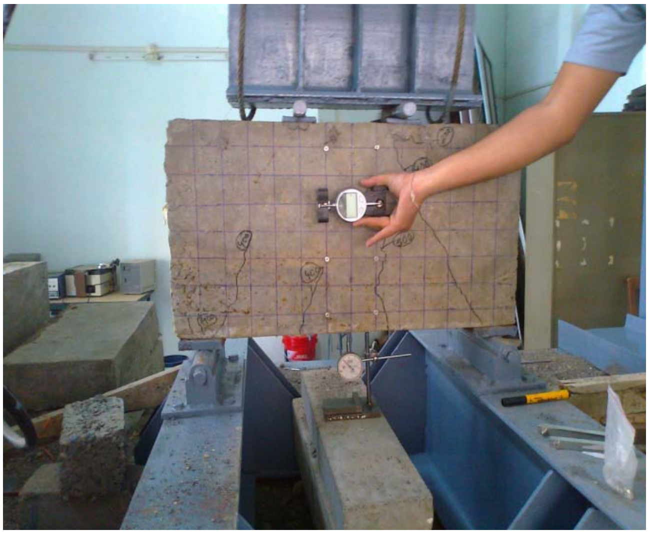


Figure 3 : Strain measurement of deep beam

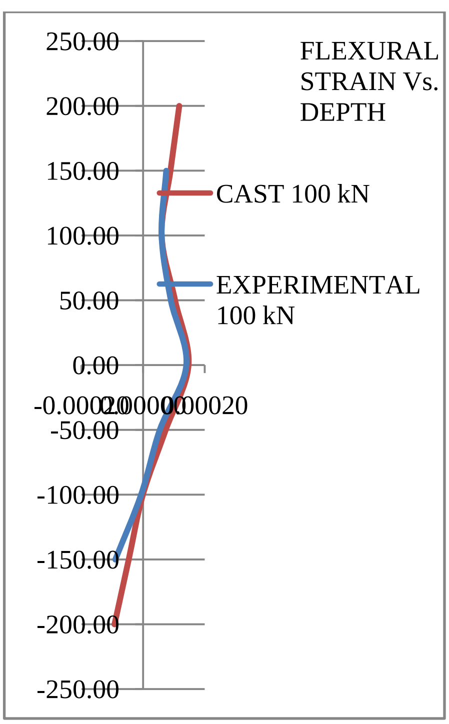
Table 1 : Experimental Strain (in mm)

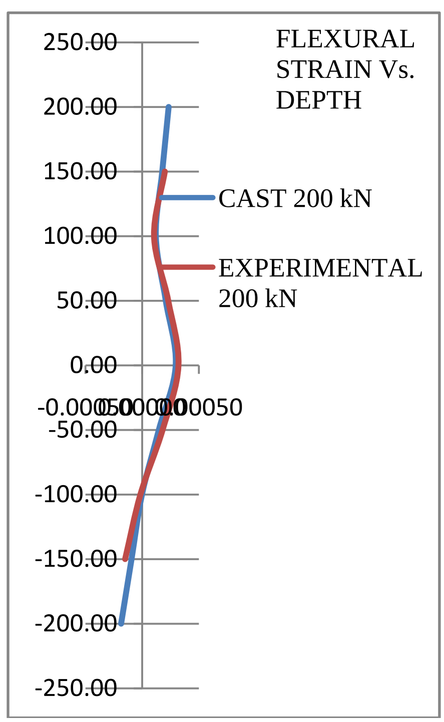
Load →	100 kN	200 kN	300 kN	400kN	440 kN
Depth ↓					
150	0.00008	0.00011	0.00022	0.00029	0.00032
100	0.00006	0.00011	0.00026	0.00036	0.00045
50	0.00009	0.00023	0.00052	0.00096	0.00121
0	0.00014	0.00035	0.00072	0.00140	0.00165
-50	0.00005	0.00019	0.00038	0.00080	0.00092
-100	-0.00001	-0.00001	-0.00002	0.00000	0.00000
-150	-0.00009	-0.00015	-0.00035	-0.00038	-0.00039

Table 2 : Analytical strain (in mm)

Load	100 kN	200 kN	300 kN	400kN	440 kN
Depth					
200.00	0.00005	0.00010	0.00014	0.00018	0.00020
150.00	0.00005	0.00010	0.00015	0.00021	0.00023
100.00	0.00006	0.00009	0.00016	0.00023	0.00026
50.00	0.00012	0.00021	0.00043	0.00071	0.00084
0.00	0.00019	0.00033	0.00070	0.00120	0.00142
-50.00	0.00011	0.00018	0.00038	0.00065	0.00077
-100.00	0.00002	0.00003	0.00006	0.00010	0.00012
-150.00	-0.00002	-0.00006	-0.00009	-0.00011	-0.00012
-200.00	-0.00007	-0.00015	-0.00024	-0.00032	-0.00036

In above table 1, shows experimental strain at mid span of deep beam at definite incremental loading at various depth to understand the nature of strain. Analytical strain obtained By using cast software are tabulated in table 2.





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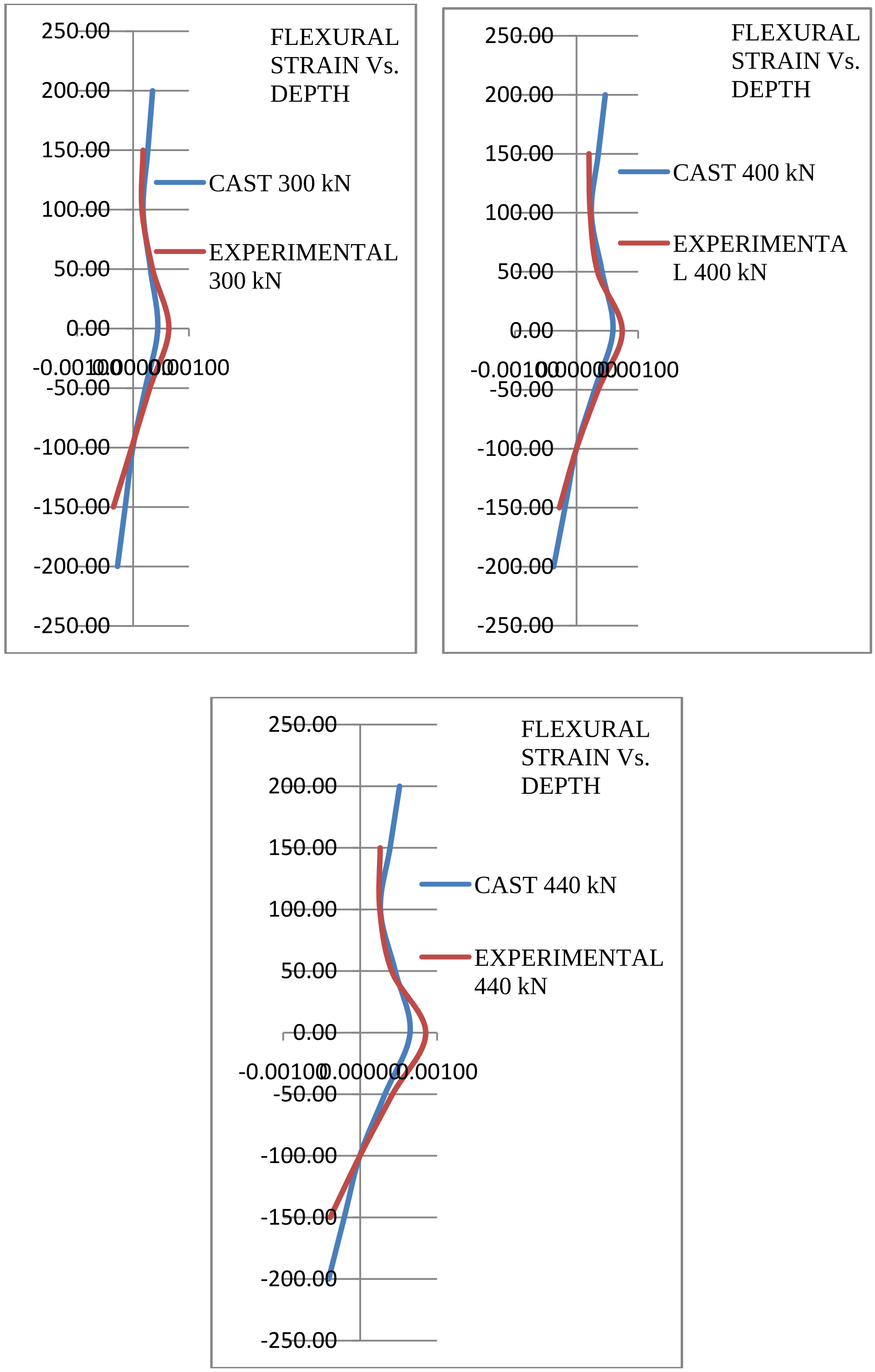

Graph 1 : Comparison of Flexural strain vs. depth

Above graph shows the comparison of experimental strain and analytical strains recorded at 100 kN, 200 kN, 300 kN, 400kN, 440kN. Experimentally deep beam designed by strut and tie method for two point loads of 50 kN (2 X 50 kN =100 kN) deep beam failed at 440 kN (220 kN each).Experimental and analytical results are almost same up to 200 kN (two point load each of 100 kN)

VI. Conclusion

1. Strut and tie method is useful to understand flow of stress.
2. CAST software gives good results which matches with experimental results.
3. Strain in deep beam is non linear along its vertical axis.

4. At design load experimental as well as analytical strain at mid span of deep beam matches with each other. With further increase in load, experimental strain goes on increasing at bottom and mid depth of deep beam. (Reference Graph 1)

References Références Referencias

1. IS : 456–2000. 'Plain and Reinforced Concrete — Code of Practice'. Bureau of Indian Standards, Manak Bhavan, New Delhi, India.
2. ACI 318–05. 'Building Code Requirements For Structural Concrete and Commentary' American Concrete Institute, Detroit, USA.
3. J Schliach and K Schafer.' Design and Detailing of Structural Concrete using Strut–and–Tie Models'. The Structural Engineer,vol 69, 1991, 113.
4. AASHTO, "AASHTO LRFD Bridge Specifications for Highway Bridges" (2001 Interim Revisions), American Association of Highway and Transportation Officials, Washington, D.C., 1998.
5. Mr. Varghese and Mr. Krishnamoorthy,(1966),Streingth and Behaviour of Deep Reinforced Concrete Beams, Indian Concrete Journal, 104-108.
6. Matamoros and Wong ,(2003), Design of simply supported Deep beam using strut -and –tie models,ACI Structural journal,704-712.
7. Quintero-Febres, Parra-Montesinos and Wight ,(2006), Strength of Struts in deep Concrete Members Designed Using Strut and Tie Method, ACI Structural journal, 577-586.
8. Park and pauly, Reinforced Concrete Structures,A wiely-Interscience Publication.
9. P. Nagarajan, Dr.T.M.M.Pillai and Dr.N.Ganesan, (2007), Design of Simply Supported Deep Beams using IS 456:2000 and Strut and Tie Method, IE (I) Journal-CV, 38-43.
10. Michael D. Brown, Cameron L. Sankovich, Oguzhan Bayrak,James O. Jirsa,John E. Breen, Sharon L. Wood, (2006), the technical report on Design for Shear in Reinforced Concrete Using Strut -and-Tie Models.
11. James k Wight and Gustavo J.Parra-Montesinos,(2003), Strut-And-Tie Model For Deep Beam Design, Concrete international,63-70.
12. Perry Adebar and Zongyu Zhou,(1993),Bearing Strength of Compressive Struts Confined by Plain Concrete,ACI Structural Jouranal,534-541.
13. Chung, W., and Ahmad, S.H., 1994, "Model for Shear Critical High-Strength Concrete Deep Beams," ACI Structural Journal, Vol. 91, No. 1, pp. 31-41.
14. Laupa, A., Siess, C.P., and Newmark, N.M., 1953, "The Shear Strength of Simple-Span Reinforced Concrete Beams without Web Reinforcement,"Structural Research Series No. 52, University of Illinois, Urbana.

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