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Analysis and Design of R.C. Deep Beams by Using Newzealand Code and Comparison with Experimental Results Using Strain Gauges

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***Abstract:** This paper describes analysis and design of beams subjected to two points loading with three different L/D ratios using non linear finite element analysis. The codes used were I.S.456-2000, NEWZEALAND, CANADIAN, CIRIA GUIDE-2(1977) and ACI 318 are used for design purpose, to plot the variation of flexural stress, strains and shear stress in deep beam.*

***Key words:** Deep Beam, code provisions, strain, stress etc.*

I. INTRODUCTION

Reinforced concrete deep beams are fairly common structural elements. They frequently occur in tall buildings, offshore structures and complex foundation systems. Deep beams are basically characterized by relatively small values of span/depth ratios. Deep beams are recognized by relatively small values of span-to-depth ratio. Beams with large depths in relation to spans are called deep beams. In IS-456 (2000) Clause 29, a simply supported beam is classified as deep when the ratio of its effective span L to overall depth D is less than 2. Continuous beams are considered as deep when the ratio L/D is less than 2.5. The effective span is defined as the centre-to-centre distance between the supports or 1.15 times the clear span whichever is less. As per New Zealand Code, Deep Beams are members loaded on one face & supported on the opposite face, so that compression struts can develop between the loads & supports,& have either; clear span , Ln equal to or less than 3.6 times the effective depth for s. s. or continuous beams ,clear span equal or less than 1.6 times the effective depth for cantilever beams. As per the Canadian code CSA 3-A23.3 defines deep beam as a beam in which the ratio of the clear span l_0 to the overall depth h is less than the limits given below. Simple spans: $l_0 / h < 1.25$, Continuous spans: $l_0 / h < 2.5$ The CIRIA Guide applies to beams having an effective span/ depth ratio l/h of less than 2 for single-span beams and less than 2.5 for continuous beams.

As per ACI-318 code provisions the deep beam is defined as the ratio of effective span to depth is less than or equal to four.

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The comparison between ANSYS results and experimental test results are made in terms of strength, flexural strain, deflection and failure load of concrete beams. The analytical and experimental flexural strains are compared at mid-section and at extreme tension & compression of the beam for different L/D ratios.

II. OBJECTIVE OF STUDIES

The main objective of this investigation is to compare the analytical strains obtained by ANSYS 9.0 and experimental strains measured using strain gauges at mid section of the deep beam under two point loading. The detailed analysis has been carried out using non-linear finite element method & design using NEWZEALAND CODE (NZS-3101-2006) New Zealand Standard CONCRETE STRUCTURES STANDARD Part-1 the Design of Concrete Structures

The objectives of the analytical and experimental investigation are listed as follows.

1. To observe & explain the deflection, cracking & failure modes of deep beams subjected to two points loading.
2. To observe flexural stress & strain variation obtained from analytical & experimental results at mid-section of the beam for different L/D ratios.
3. To observe shear stress variation obtained from analytical results near the support of the beam for different L/D ratios.

III. ANALYTICAL AND EXPERIMENTAL INVESTIGATION

For the study and behavior of the deep beams the non-linear finite element analysis has been carried out to find out the variation in strains, flexural steel and flexural stress in the deep beam.

For the design and experimentation purpose three L/D ratios each l/D ratio having three specimens were cast and tested in the heavy structures laboratory. The experimental set up for the testing of the beams were shown in the fig .1. The beams were designed by the provisions given by the NEWZEALAND code and the method used for the design is STRUT and TIE method of the ACI -318 code provisions. The comparison between experimental and analytical results has been carried out. The average results of the analytical and experimental were taken for the study purpose.

Beam no 1- NZS 400 :>

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In the fig.2 shown the beam was designed by the NEWZEALAND CODE having dimensions L=700 mm, D=400 mm. B=150 mm and the two point loading were applied to the given beam. Two point loads of 50 KN were applied on the beam. After every 50KN load interval the strains were measured. The initial cracking at the point of support bearing was observed at 100 KN, and the cracking pattern was observed in the middle and diagonal portion of the beam at 300 KN. After that we stopped the application of loading at 400KN and simultaneously the strains were measured. The graph of the experimental strain and theoretical strain was plotted and as shown in the fig. 2.1 and also the shear stress distribution diagram were plotted as shown in the fig. 2.2.

Fig.1 Experimental Set Up

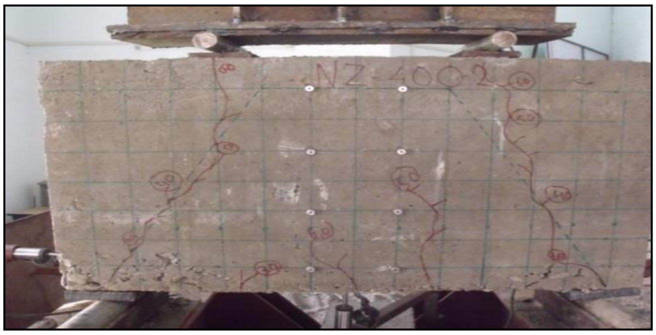
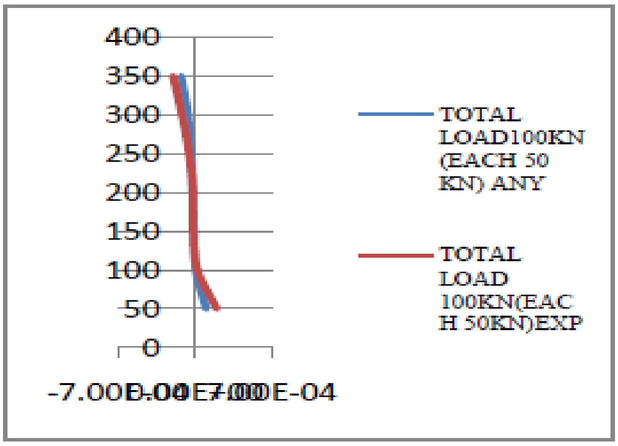
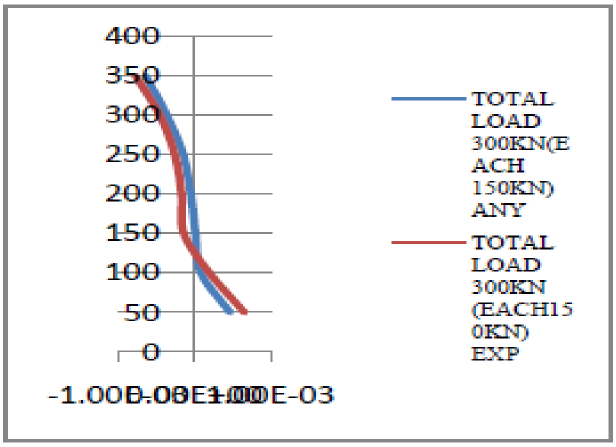


Fig.2 Beam no1 NZS 400 mm





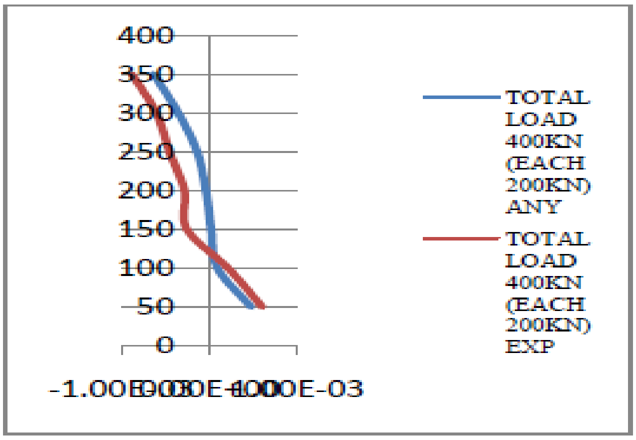
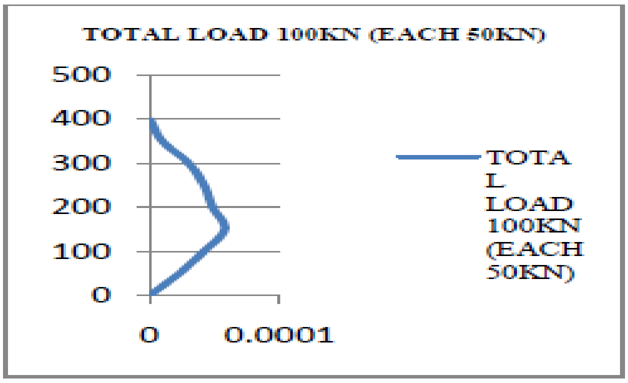
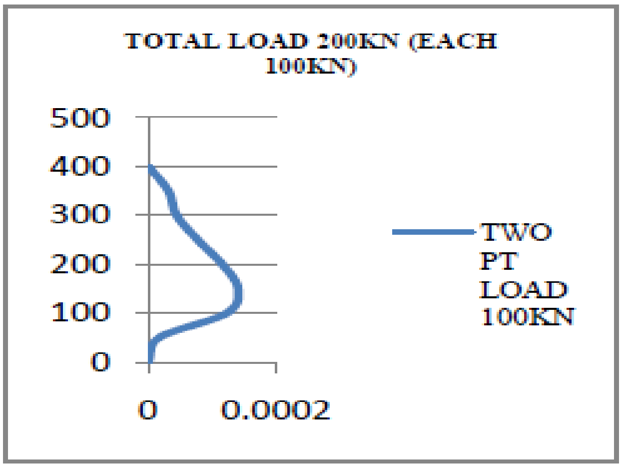


Fig.2.1 Analytical and Experimental Strain Diagram for NZS code 400mm depth and L/D ratio 1.5





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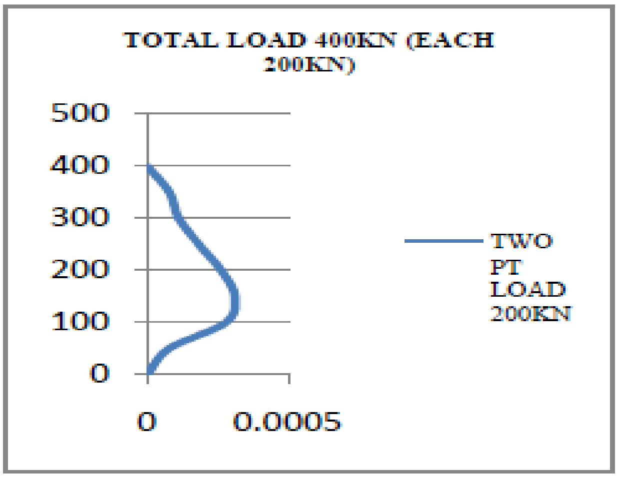
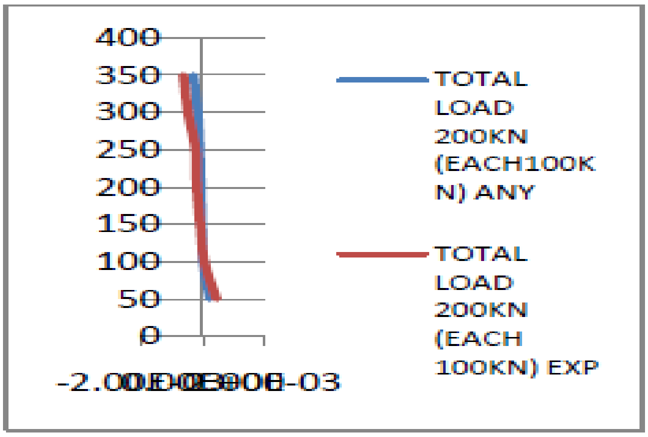
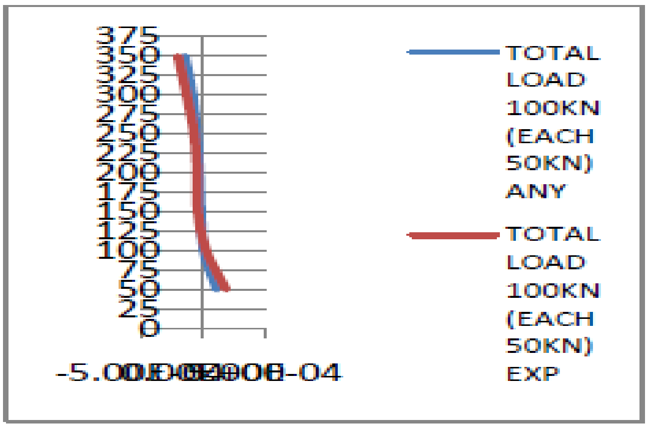


2.2 Shear Stress Distribution Diagram

Beam no 2- NZS 375:>

In the fig.3 shown the beam was designed by the NEWZEALAND CODE having dimensions L=700 mm, D=375mm. B=150 mm and the two point loading is applied to the given beam .Two point loads of 50 KN were applied on the beam. After every 50KN load interval the strain were measured. The initial cracking was observed at 200 KN load at point of support of bearing at top, and the cracking pattern was observed in the middle and diagonal portion of the beam at 300 KN. After that we stopped the application of loading at 375KN and simultaneously the strain is measured. The graph of the experimental strain and theoretical strain was plotted and as shown in the fig.3.1 and also the shear stress distribution diagram were plot as shown in the fig. 3.2 below





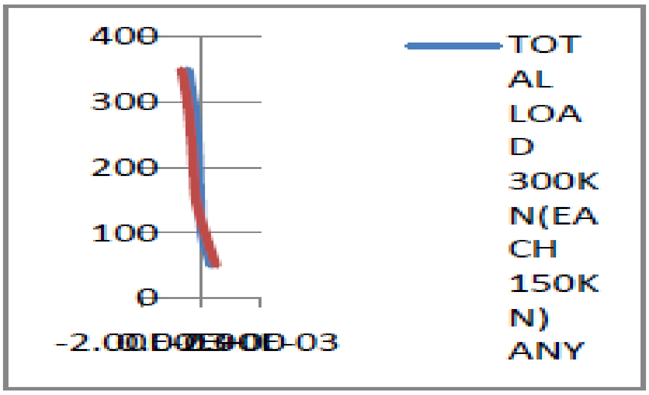
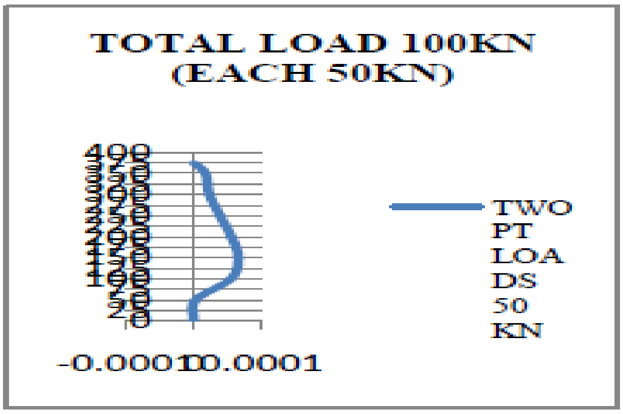
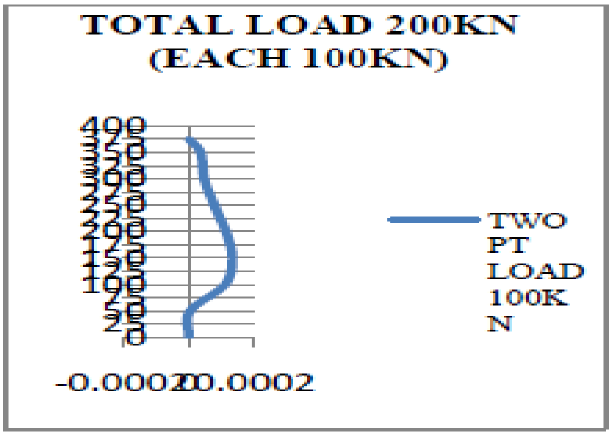


Fig.3.1 Experimental and Analytical Strain Diagram





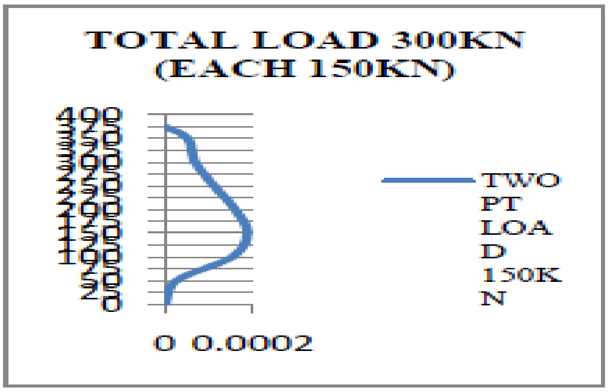


Fig.3.2 Shear stress DistributionDiagram

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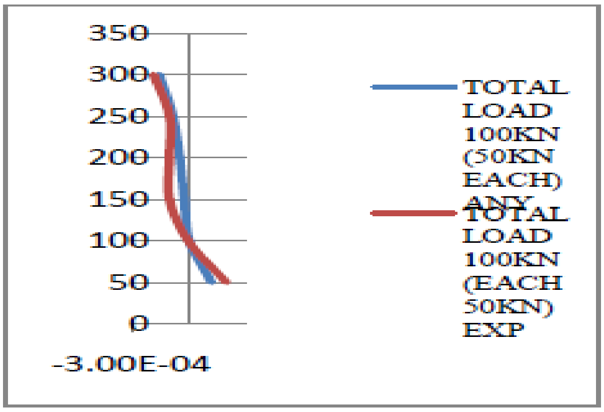
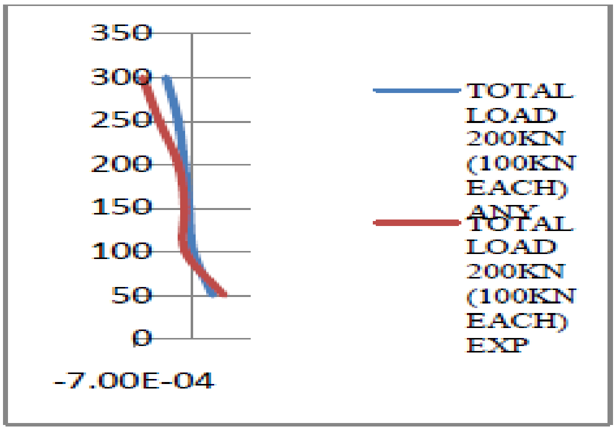
Beam no 3- NZS 350:>

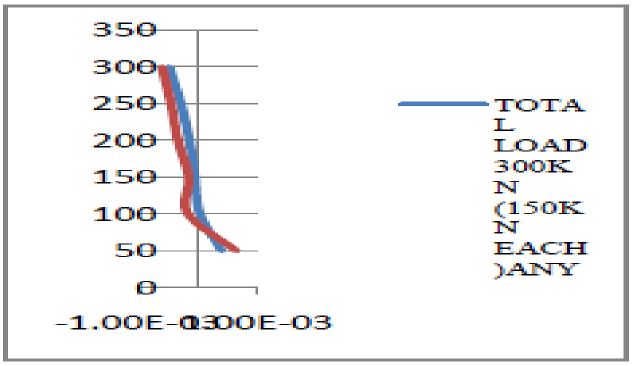
In thefig.4 shown the beam was designed by the NEWZEALAND CODE having dimensions L=700 mm, D=350 mm. B=150 mm and the two point loading were applied to the given beam. Two point loads of 50 KN were applied on the beam. After every 50KN load interval the strain were measured .the initial cracking was observed at 200 KN load at point of support of bearing at top, and the cracking pattern was observed in the middle and diagonal portion of the beam at 300 KN. After that we stopped the application of loading at 375KN and simultaneously the strain is measured. The graph of the experimental strain and theoretical strain was plotted and as shown in the fig.4.1 and also the shear stress distribution diagram were plot as shown in the fig. 4.2 below.

Fig.4 Beam no 3- NZS 350

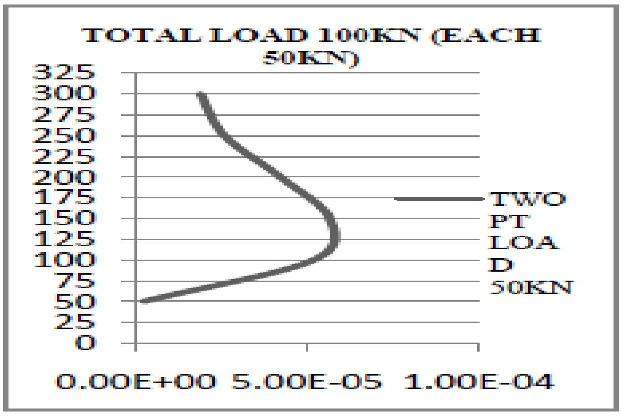
Fig.3 Beam no 2 NZS 375 mm

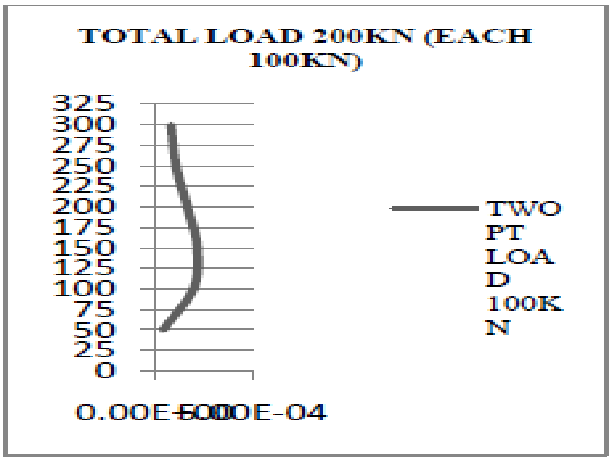






4.1 Experimental and Analytical strain Diagram





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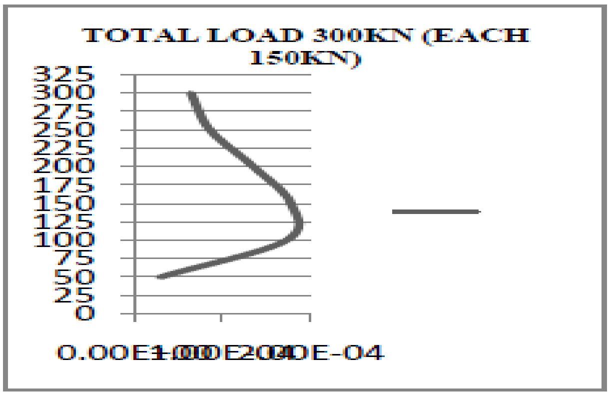

4.2 Shear stress Distribution Diagram

The following tabels i.e. from table number 1 to 6 were prepared to compute the percentage increase in the therotical and experimental strains at load when the first crack was observed on the beam and the load at which the maximum cracks were observed on the beam.

TABLE NO-1 PERCENTAGE INSREASE IN STRAIN at first crack for 350 mm depth and L/D Ratio 1.71

PERCENTAGE INSREASE IN STRAIN				
Load At First Crack	**Depth**	**Analytical**	**Experimental**	**Percentage Insrease**
130KN	TOP	2.29E-04	2.40E-04	4.8
	MIDDL E	3.16E-05	3.40E-05	7.59
	BOTTO M	7.69E-05	8.70E-05	13.13

TABLE NO- 2 PERCENTAGE INSREASE IN STRAIN at maximum crack load for 350 mm depth and L/D/ Ratio 1.71

PERCENTAGE INSREASE IN STRAIN				
Load At Max Crack	**Depth**	**Analytical**	**Experimental**	**Percentag e Insrease**
375 KN	TOP	4.77E-04	6.00E-04	25.78
	MIDDLE	4.68E-05	2.40E-05	20.52
	BOTTOM	4.06E-04	5.10E-04	25.62

TABLE NO-3 PERCENTAGE INSREASE IN STRAIN at first crack for 375 mm depth and L/D/ Ratio 1.6

Load At First Crack	**Depth**	**Analytical**	**Experimental**	**Percent age Insrease**
150KN	TOP	2.13E-04	2.30E-04	7.98
	MIDDLE	3.84E-05	4.00E-05	4.16
	BOTTOM	7.53E-05	8.00E-05	6.24

TABLE NO- 4 PERCENTAGE INSREASE IN STRAIN at maximum crack for 375 mm depth and L/D/ Ratio 1.6

Load At Max Crack	Depth	Analytical	Experimental	Percentage Insrease
375 KN	TOP	4.24E-04	5.50E-04	29.71
	MIDDLE	3.38E-04	4.50E-04	33
	BOTTOM	3.38E-04	4.30E-04	27.21

TABLE NO-5 PERCENTAGE INSREASE IN STRAIN at first crack for 400mm Depth and L/D Ratio 1.5TABLE 5

Load At First Crack	**Depth**	**Analytical**	**Experimental**	**Percentage Insrease**
150KN	TOP	1.90E-04	2.10E-04	10.52
	MIDDLE	3.13E-05	4.00E-05	7.8
	BOTTOM	1.56E-04	1.75E-04	12.17

TABLE NO- 6 PERCENTAGE INSREASE IN STRAIN at maximum crack for 400mm Depth and L/D Ratio 1.5

Load At First Crack	**Depth**	**Analytical**	**Experimental**	**Percentage Insrease**
440 KN	TOP	6.42E-04	8.50E-04	32.4
	MIDDLE	4.64E-05	5.80E-05	25
	BOTTOM	4.68E-04	6.10E-04	30.34

CONCLUSIONS

As L/D ratio decreases there is an increase in the strain of the deep beams has been observed, L/D ratio is inversely proportional to strain of the beam i.e.
At the load of maximum cracks:

1. For L/D ratio 1.5 there is an 32.40 % increase in the experimental strain with respect to analytical strain at the compression, 25 % at the mid depth of the beam and 30.34 % increase at the bottom i.e.at tension of the deep beam.
2. For L/D ratio 1.5 there is a 29.71 % increase in the experimental strain with respect to analytical strain at the compression, 33 % at the mid depth of the beam and 27.21 % increase at the bottom i.e.at tension of the deep beam.
3. For L/D ratio 1.5 there is a 25.78 % increase in the experimental strain with respect to analytical strain at the compression, 20.52 % at the mid depth of the beam and 25.62 % increase at the bottom i.e.at tension of the deep beam.

REFERENCES

1. AASHTO, "AASHTO LRFD Bridge Specifications for Highway Bridges" (2001 Interim Revisions), American Association of Highway and Transportation Officials, Washington, D.C., 1998.
2. APENDIX A OF ACI-318 AMERICAN CONCRETE INSTITUTE (BUILDING CODE REQUIREMENT FOR STRUCTURAL CONCRETE ACI -318-2005 AND COMMENTARY ACI- 318R-2005).
3. ACI-318-2005 AMERICAN CONCRETE INSTITUTE (BUILDING CODE REQUIREMENT FOR STRUCTURAL CONCRETE ACI -318-2005 AND COMMENTARY ACI- 318R-2005).

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4. 'British code of practice' B.S.8110-02 (BRITISH STANDARD Structural Use of concrete part-1 Code of practice for design and construction)
5. CANADIAN CODE (CSA-A23.3-2004) (CANADIAN STANDARD ASSOCIATION Design of Concrete Structures)
6. CIRIA Guide 2 (1977), "The design of deep beams in reinforced concrete", Over Arup and Partners and Construction Industry Research and Information Association, London, (reprinted 1984), 131 p.
7. 'Design by Strut and Tie method using ACI Appendix A' from STM website.
8. Indian Standard Code of Practice Plain and Reinforced Concrete' IS 456:2000-. Bureau of Indian Standards, Manak Bhavan, New Delhi, India.
9. Marti Peter, 'Basic Tools of Reinforced Concrete Beam Design' ACI journal, Title no. 82-4, January-February 1985.
10. Kong. F. K. 'Reinforced Concrete Deep Beam', Van No strand Reinhold, New York
11. Mr. Kotsovos, 'Design of Reinforced Concrete Deep Beams' Journal of Structural Egg., 28-32, January 1988.
12. Matamoros and Wong, 'Design of Simply Supported Deep Beam using strut and tie models' ACI Structural journal, 100-S72, November/ December 2003.
13. Mohammed Reza Salamy,Hiroshi Kobayashi and Shigeki Unjoh. 'Experimental and Analytical Study on Deep Beams'
14. 'NEWZEALAND CODE (NZS-3101-2006) New Zealand Standard CONCRETE STRUCTURES STANDARD Part-1 The Design Of Concrete Structures
15. Nagarajan P, Dr Pillai M M T and Dr Ganesan N, 'Design of simply supported Deep Beam using IS 456: 2000 and Strut and Tie Method'. IE (I) Journal-CV Vol.88 38-43, May 2007.
16. Park R. and Pauly T. 'Reinforced Concrete Structures', Wiely-Interscience Publications.
17. Quintero-Febres, Parra-Montesinos and Wight, 'Strength of Struts in Deep Concrete Members using Strut and Tie Method', ACI Structural journal, 103-S61, July/ August 2006.
18. Rogowsky. David M., MacGregor James G. and See Y. Ong, 'Tests of Reinforced Concrete Deep Beam'. ACI Journal 614-623, july-August-1986.
19. Schleicher J. and Schafer .K.' Design and Detailing of Structural Concrete using Strut–and–Tie Models'. The Structural Engineer, vol 69, 1991, 113.
20. Varghese and Krishnamurthy, 'Strength and Behavior of Deep Reinforced Concrete Beams' Indian Concrete Journal, 104-108, March 1966.
21. Varghese P.C. 'Advanced Reinforced Concrete Design', Prentice Hall of India Pvt.Ltd. New Delhi.

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