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# EXPERIMENTAL STUDY ON THE INCREASED COVER SPECIFICATIONS OF IS 456-2000 IN RC SLABS FOR SEVERE EXPOSURE WITH MINIMUM %GE OF STEEL

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## ABSTRACT

Continuous research focuses on gaps in knowledge and the research findings renovate the role of concrete industry to a higher, newer and more useful level of performance. Many reinforced concrete structures built in the not-too-distant past, in adverse environments have shown signs of increased structural distress and some structures even collapsed mainly due to chemical or climatic attack causing deterioration of concrete and corrosion of reinforcing steel. The code explicitly states that the spacing requirement of the reinforcement specified for Reinforced Concrete slabs, should be sufficient to control flexural cracking, for the maintenance of durability. The objective of the presented research is to investigate the validity of the specified clause of the IS 456:2000 code relative to durability. Severe exposure case is taken for investigation in the current research.

***Keywords****: renovate; reinforced concrete; deterioration; corrosion; flexural cracking; durability; Severe exposure*

## I. INTRODUCTION

Code IS 456:2000 is the most influential and extensively used code in India and plays a leading role in many ways related to concrete and reinforced concrete in the areas of education, research, design, production, construction, infrastructure projects, repair and retrofit. If concrete is to serve the purpose for which it is designed during its intended lifetime it has to be durable. Durability has occupied center stage in activities of concrete technology for a few decades. Both the requirements of crack width and cover are to be coupled to meeting durability requirements.

When tensile stress in concrete exceeds its tensile strength crack forms. There are three reasons for limiting the crack widths in structures. These are: 1.Appearance 2.Durability and 3.Liquid tightness. These three requirements are not applicable simultaneously in a particular structure. Cracks greater than 0.3mm allow ingress of moisture and chemical attack to the concrete resulting in corrosion to steel reinforcement. In harmful or severe environments even lesser widths 0.2 and 0.1mm cause damage as per code. Deterioration of concrete and corrosion of reinforcement have caused innumerable damages and even collapse of structures world over with low tensile stresses in the reinforcements at service loads, the structure exhibited limited low crack widths, and served their needed functions without any distress due to induced cracking; this helped preservation of durability in reinforced concrete structures. The cover varies from 20 to 75mm as per environmental exposure condition. Depending upon the exposure condition code specifies in Table minimum 5 of IS 456-2000, cement content, maximum free water cement ratio and maximum grade of concrete. The surface width of the cracks should not, in general, exceed 0.3mm in members where cracking is not harmful and does not have any serious adverse effects upon the preservation of reinforcing steel nor upon the durability of the structures. The test programme is initiated to investigate the influence of increased concrete covers in reinforced concrete slabs, stipulated in the IS 456:2000 on the development of induced crack widths when the detailing of steel reinforcement is as per codal specification.

## II. EXPERIMENTAL INVESTIGATION

### Specimen details and materials

In the experimental programme undertaken, four full scale slabs, were designed to serve in severe exposure conditions and tested under simply supported and uniformly distributed load. All the slabs were identical in geometry measuring 600mm in width and 2.8m in length. The simply supported effective span was 2.5m. The overall depth of the slab varied in accordance with the exposure conditions. Severe exposure slabs were 125mm deep. The minimum weight of the slab was 4.69kN, requiring 120kN crane for its transport. The nominal covers of the slabs 45mm for severe exposure slabs. As per Table 5 of IS 456:2000, the properties of the concrete, the minimum cement, maximum water cement ratio and minimum grade of concrete are respectively 320kg/m$^3$ (3.2kN/m$^3$), 0.45 and M30 for severe exposure case.

***Fig 1 Reinforcement details of SV1 & SV2***

For each exposure condition varying percentage of steel reinforcement starting with a minimum value were adopted. The percentage of flexural reinforcement varied from a maximum value, which is more than the minimum specified by the code, 0.12 percent of the total cross sectional area with high strength deformed bars to near maximum permissible value. Spacing requirement of flexural reinforcement in slabs was in compliance with codal specification. As reinforcement detailing satisfied the codal requirements, the slabs should not violate the stipulated crack width requirements. The codal requirements for exposure conditions are tabulated in Table 1. The experimental details of the slabs adopted are furnished in Table 2. The reinforcement details of the slabs are shown in Fig 1. The distribution steel used was mild steel 6mm dia bars at 0.15 percent of the total cross section area.

The fine aggregate used was river sand conforming to zone-II and coarse aggregate was well graded combination of maximum size 20mm and 10mm in the ratio of 3:2; The slabs are designated by 2 letters and a numeral. Severe exposure slabs are SV1 and SV2. For severe exposure slabs the concrete mix proportion was 1:1.94:2.72 by weight with water cement ratio of 0.45. The target strength was M30 (30MPa).

***Table. 1 Details of test slabs***

| **Slab label** | **Type of exposure** | **Flexural reinforcement and spacing (mm)** | **$P_t = (A_{st}/bD) \times 100$** | **Compressive strength at the time of testing (MPa)** | **Split tensile strength at the time of slab testing (MPa)** | **Total design load at ultimate (kN)** | **Total design load at service (kN)** |
|---|---|---|---|---|---|---|---|

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|---|---|---|---|---|---|---|---|
| SV 1 | Severe | 3-8Ø @ 221 c/c | 0.20 | 37.3 | 3.05 | 15.10 | 10.07 |
| SV 2 | Severe | 6 -8Ø @ 106.4 c/c | 0.40 | 37.3 | 3.05 | 28.43 | 18.95 |

Cement mortar cover blocks of adequate size and strength at needed spacing were provided to steel reinforcement. The concrete was machine-mixed and poured in slab moulds in two layers; each layer was vibrated with needle immersion vibrator and flat vibrator up to total depth of slab. The top surface of the slab was smoothened with trowel and all the slab specimens were kept under moist curing in the laboratory. For concrete compressive and tensile strength adequate number of 150mm cubes and 150x300 mm cylinders were cast and cured along with the test slab specimens.

## III. DETAILS OF TESTING

The slabs were tested in the laboratory. The load test set-up was constructed in the laboratory by erecting two pedestals of plan size 250x700mm separated by about 2.5m with a height of 750mm. Sand bag loading was adapted as live load for testing. Sand bags each weighing 0.4 kN were laid on the top of the slab; in the span six bags were necessary touching each other. The width of the each sand bag was 600mm occupying the whole width of the slab. Each sand bag weighed 0.4 kN, 6bags touching each other occupied full span of 2.5m, weighed 2.4kN. Each layer of sand bags with a weight of 2.4kN was treated as one load stage. The slabs were instrumented for the measurement of deflection at mid-span and crack widths at each load stage. A hand held microscope with a least count of 0.1mm capable of measuring a minimum crack width of 0.05mm by judgment was used. A dial gauge was used under the slab at mid span, the least count of the dial gauge was 0.01mm. At each load stage maximum crack width, deflection and the total super imposed load on the slab were measured and noted. Cracks on both vertical side faces were marked and the maximum crack width was measured at each load stage. The slabs were tested to design ultimate load.

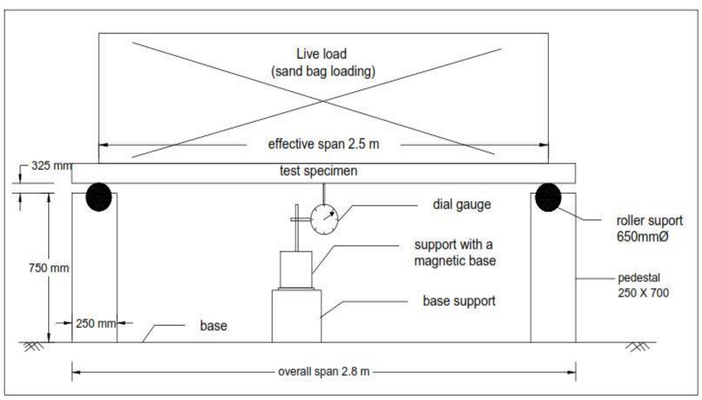


*Fig 2 Schematic loading diagram*

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***Fig 3 Live load with sand bags on test slabs.***

## IV. DISCUSSION OF TEST RESULTS

Slabs SV1 and SV2 assumed to occur in severe exposure case are designed with increasingly varying flexural reinforcement for normally occurring loads in practice. To bear these design service live loads of 6.94kN and15.83kN respectively, slabs SV1 and SV2, are designed; the corresponding live load intensities of the slabs are 4.63 kN/m2 and 10.55 kN/m2. These intensities of load are representatives of actual situations in practice such as residence, office, library, parking, industry etc. The permissible crack width as per Cl: 35.3.2 of the code, for slabs situated in severe exposure is 0.1 mm. The cover used in this case is 45mm.

Slab SV1 at service load of 10.07kN, developed a crack width of 0.22mm which is greater than the permissible value of 0.1mm. The slab becomes undurable. At slightly lower load of 9.49 kN, slab showed a crack width of 0.2mm.

In slab SV2, at its service load of 18.95kN, no crack was developed. Permissible crack width of 0.1mm was developed at load of 21.49kN which was greater than service load. The slab SV2 is durable. Except slab SV2, all the slabs in the severe exposure case are undurable.

***Fig 4 Slabs SV1 & SV2 after testing***

Under serviceability criteria deflections of structural members at service load are necessary. Test values were high for slabs SV1 and SV2 when calculated using British code. Deflections have estimated using I.S. code by two methods; in the first case with uncracked section and the second case with cracked section. The test values are higher with uncracked section except in slab SV1, and lower for than those with cracked section when computed by I.S. code.

## V. CONCLUSION

Based on the findings of this investigation, the following conclusions may be drawn

1. The experimental investigation undertaken has demonstrated that for severe environmental exposure condition, the codal assurance that mere adoption of detailing of steel reinforcement specified in the codal provision Cl: 26.3, would ensure durability relative to crack growth, is not totally valid.
2. In the slabs planned for severe exposure, slab SV1, with small percentage of steel, developed a crack width of 0.22mm, in excess of permissible value of 0.1 mm at service load of 10.07kN, making the slab undurable.
3. Slab SV2 did not develop a crack at service load of 18.95kN, rendering it durable.
4. In severe exposure only SV2 slab is durable, the slab SV1 is undurable.
5. Crack widths were estimated by American code and IS code. American code over estimated test values, while Indian code values were nearly equal to the test values.
6. Deflections are computed by IS code and British code. As per IS code, deflections were under estimated except for SV1 when uncracked section was used and overestimated when cracked section was used

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