

Comparative study for flexure design using IRC 112:2011 & IRC 21:2000

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ABSTRACT

Bridge design practices vary extensively throughout the world. Many codes are currently dealing with Limit state method; In India IRC has published new code IRC-112:2011 that combines specifications for both RCC & prestress concrete bridges. They introduces durability of concrete, general detailing requirements of different bridge members, grade of concrete is allowed up to M90 & grade of steel used up to Fe600. Compare to IRC-21:2000 that for RCC road bridges, the new code introduces Limit state method. The paper describes the flexure design approach by both the code. Emphasis is put on the variation in amount of steel by both. It also shows the design charts for particular grade of concrete and steel for various moment capacities. As it always a question how it differs from older one whenever there's new code of practice, this paper will guide for flexure design for different combination of grade of concrete & steel.

1. Limit state of internal stress
2. Limit state of crack control
3. Limit state of crack control
4. Limit state of vibration
5. Limit states of fatigue

From this, Limit state for vibration & Limit state of fatigue are not covered i.e. specialized literature are suggested by the code.

KEY WORDS

%p steel, Limiting Moment, %p steel difference for WSM & LSM, Steel & concrete grade combination.

INTRODUCTION

Code for RCC road bridges IRC 21 & prestress bridges IRC 18 are published in 2000, since to introduce Limit state method for both prestress & RCC, Indian road congress has decided to introduce a single code that defines limit state. This code combines both prestress & RCC as well as working stress method in annexure. New concepts like general basis of design, analysis's general provision, Ultimate limit state of strength & serviceability, basic variables of various a their combinations, ductile detailing for seismic resistance, durability of concrete, etc. In this paper %p difference of steel for varying grade of steel keeping cross sections, moment & grade of concrete constant & for different grade of concrete for constant cross section, moment, & grade of steel.

BASIS OF DESIGN

New concepts of Actions & their combinations gives idea about various design situation like persistent, transient, accidental or seismic combinations that might occur during the life of the structure. This will help bridge designer to design bridge for worst loading situations.

ULTIMATE LIMIT STATES

Five new limit states is introduced in new code they are

1. Limit state of equilibrium
2. Limit state of strength

SERVICEABILITY LIMIT STATES

REPRESENTATIVE VALUES OF ACTIONS & THEIR COMBINATIONS

Basically there are four different representative values of actions & their combinations are given. The characteristic values are statically extreme values. The other representative values are called the combination value, frequent value and quasi-permanent value. They are determined by multiplying the characteristic value by ψ_0 , ψ_1 and ψ_2 respectively. The combination, frequent and quasipermanent values are less statistically extreme than the characteristic value, so ψ_0 , ψ_1 and ψ_2 are always less than 1.

GENERAL DETAILING REQUIREMENT

This section is very improved compare to old code, this sections gives detailing requirement each member of bridge. It will help designer to check for minimum steel & maximum steel requirements, deflection criteria, minimum cover for different members, minimum bar size, etc.

PARAMETRIC STUDY

IRC 112 has allowed both parabolic-rectangular diagram & equivalent rectangular diagram for flexure design. In this paper equations are developed for parabolic-rectangular-diagram. Fig-1 shows the stress-stress diagram for given section, for values of strain of steel table 18.1, page 201 & for stain values of concrete are given in table 6.5, page 38 of IRC 112. By comparing %p steel for different grade of concrete & steel, we can see the difference between WSM & LSM for same cross section & moment. In the figure $\eta = \frac{\alpha}{\gamma}$ is partial factor of safety for concrete that is 1 for basic combination & 1.5 for accidental & seismic combination & for steel 1.15. Different values for WSM equations are given in annexure of IRC 112:2011.

BY CONSIDERING COMPRESSION FORCE FOR LSM

$$M, \text{lim} = C * f_{ck} * b * d^2 * \frac{x_{u, \text{max}}}{d} * (1 - B * \frac{x_{u, \text{max}}}{d})$$

Where,

C = co-efficient depends on strain values of material

fck = Grade of concrete

b = breadth of the section

d = effective depth of the section

B = Coefficient depends on geometry of stress diagram.

Xu,max = limiting value of the neutral axis for given section

BY TAKING TENSILE FORCE FOR LSM

$$M_u = 0.8 * f_y * A_{st} * b * (1 - B * \frac{X_{u,max}}{d})$$

Where,

0.8 is constant for limiting stress value.

f_y = grade of steel

A_{st} = Area of steel provided or required.

b = breadth of the section

B = coefficient depends on geometry of the section.

X_{u,max} = limiting value of the neutral axis for given section.

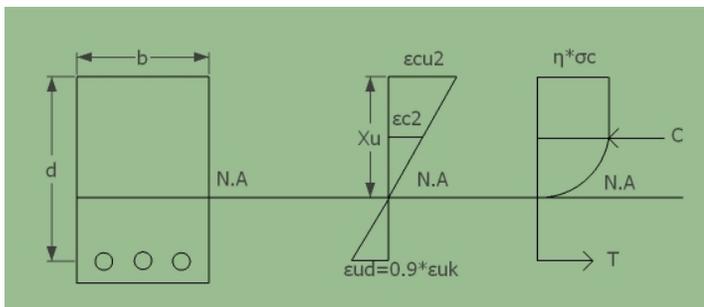


FIG-1 STRESS-STRAIN DIAGRAM

For Working stress method following equations are used

CONSIDERING COMPRESSIVE FORCE IN THE SECTION FOR WSM

$$M_{bal} = 0.5 * \sigma_c * n * j * b * d^2$$

Where,

σ_c = Limiting value for concrete

$$n = \frac{m * \sigma_c}{m * \sigma_c + \sigma_s}$$

m = modular ratio = 10 given by IRC 21:2006

σ_s = limiting value of stress for steel.

$$j = 1 - n/3$$

BY TAKING TENSILE FORCE FOR WSM

$$M = \sigma_s * A_{st} * j * d$$

Where, σ_s = Limiting value for the steel

$$j = 1 - n/3$$

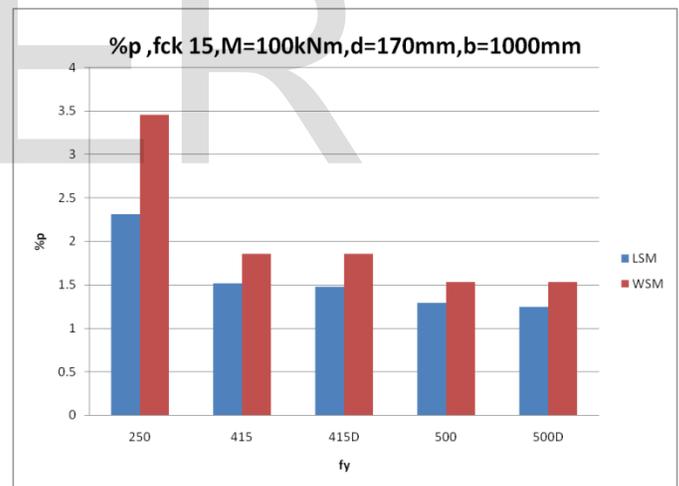
d = effective depth of the section.

A_{st} = Area of the steel provided or required.

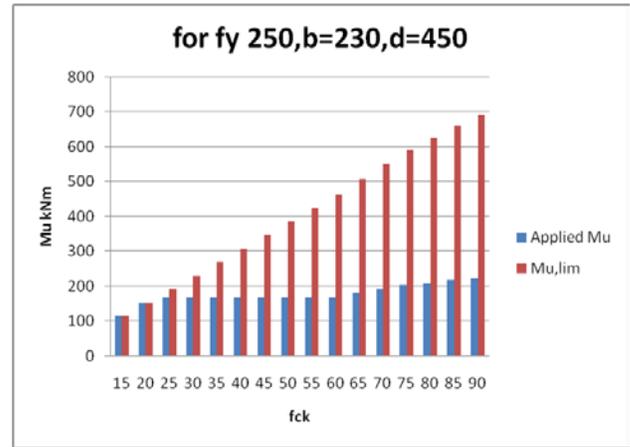
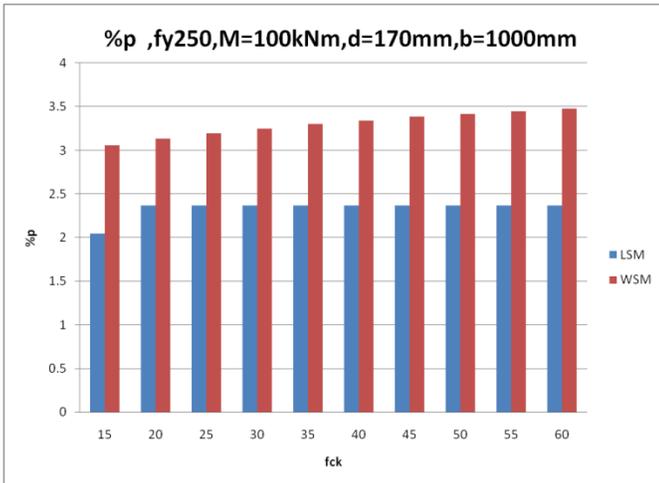
Using above equations 8 different graph are shown below, where

$$\%p = \frac{100 * A_{st}}{b * d}$$

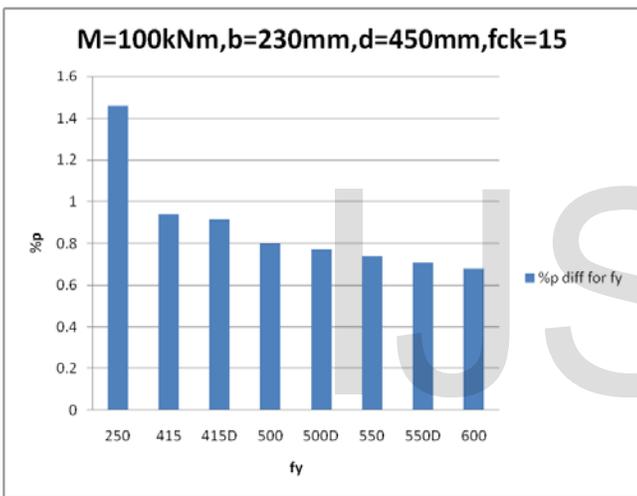
1. %p vs varying f_y = grade of steel, for b = 1000mm, d = 170mm & f_{ck} = 15.



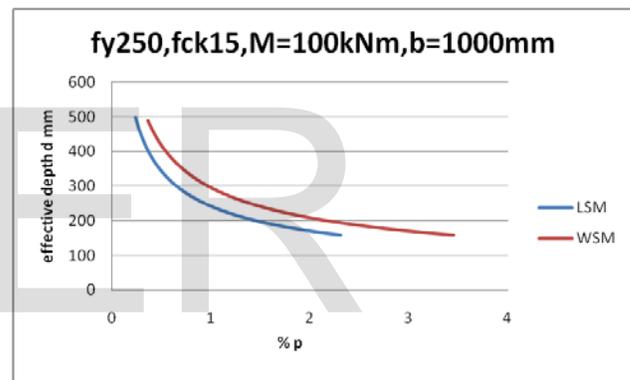
2. %p vs varying f_{ck} = grade of concrete, for b = 1000mm, d = 170mm & f_y = 250.



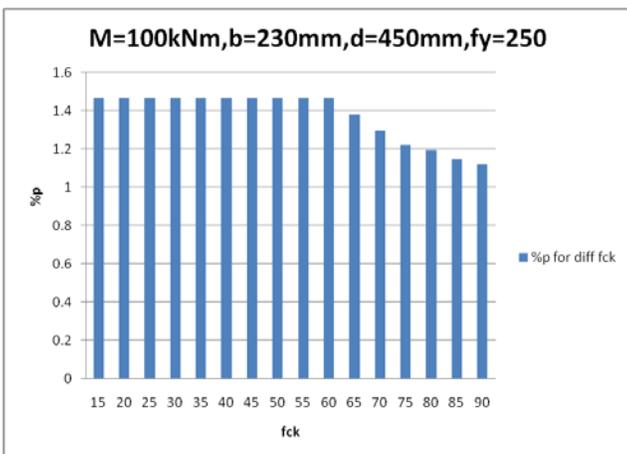
3. %p vs fy for M=100kNm, b=230mm, d=450mm, fck=15



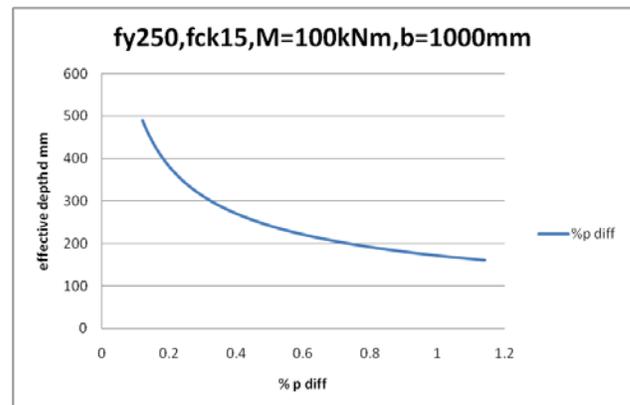
6. effective depth vs %p, for b=1000mm, M=100kNm, fy=250 & fck = 15



4. %p vs fck for M=100kNm, b=230mm, d=450mm, fy=250



7. effective depth vs %p difference, for b=1000mm, M=100kNm, fy=250 & fck = 15



5. Mu vs fck for fy=250, b=230mm, & d=450mm.

CONCLUSION

Based on above graph following conclusions are done.

1. In 1st & 2nd graph we clearly see that for the same cross section & same applied moment & steel difference is quite noticeable compare to WSM, LSM is about 16 to 18 % more economic i.e consumes less steel than WSM.

2. %p difference pattern for LSM are same in 1st graph, but it's almost constant in 2nd graph & It's linearly increasing for WSM.

3. By observing 3rd & 4th graph, we can conclude that for same cross section & same moment more %p difference is achieved by just increasing fy grade of steel but it's constant for M15 to M60,i.e it's better to change grade of steel rather increasing grade of concrete for more %p steel difference.

4. In 5th graph Mu,lim of the section is increased as grade of concrete increased but applied moment are restricted due to provision of maximum steel criteria.

5.6th & 7th graph shows gradual varying pattern of %p steel of WSM & LSM steel requirement for same cross section, material & same applied moment, for above case it's lies between 0.1% to 1.1%,i.e WSM consumes more steel by this much %p of steel.

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