STUDY OF COST EFFECTIVENESS IN DESIGN OF STRUCTURES WITH HIGH PERFORMANCE CONCRETE

A Project Submitted
In Partial Fulfilment of the Requirements
For the Degree of

Bachelor of Technology
In Civil Engineering
By

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Roll no.-10401007
&
Sunil kumar Sahoo
Roll No.-10401025

DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY ROURKELA
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Under the guidance of

Prof. A.K.Sahoo

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CERTIFICATE

This is to certify that the project entitled "**Study of cost effectiveness in Design of Structures with High Performance Concrete"** submitted by Indubhusan Jena [Roll no. 10401007] and Sunil Kumar Sahoo [Roll no. 10401025] in partial fulfilment of the requirements for the award of Bachelor of Technology degree in Civil engineering at the National Institute of Technology Rourkela is an authentic work carried out by them under my supervision and guidance.

To the best of my knowledge the matter embodied in the project has not been submitted to any other university/institute for the award of any degree or diploma.

Date:

Prof A.K.Sahoo
Department of Civil Engineering
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Rourkela - 769008

ACKNOWLEDGEMENT

We wish to express our deep sense of gratitude and indebtedness to **Prof. A.K.Sahoo,** Department of Civil Engineering, N.I.T Rourkela for introducing the present topic and for his inspiring guidance, constructive criticism and valuable suggestion throughout this project work.

We would like to express our gratitude to **Dr.K.C.Patra (**Head of the Department), for his valuable suggestions and encouragements at various stages of the work.

We are also thankful to all the staff in Department of Civil Engineering for providing all joyful environments in the lab and helping us out in different ways.

Last but not least, our sincere thanks to all our friends who have patiently extended all sorts of help for accomplishing this undertaking.

Date: **IndubhusanJena**

Sunil Kumar Sahoo

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Abstract: High Performance Concrete can be considered as a logical development of cement concrete in which the ingredients are proportioned and selected to contribute efficiently to the various properties of cement concrete in fresh as well as in hardened states. Higher strength is one of the features of High Performance Concrete which provides significant structural advantages. The three major components contributing to the cost of a structural member are concrete, steel reinforcement and formwork .This paper aims at comparing these major components when concrete of higher grade is used in the design and to establish that High strength concrete provides the most economical way for designing the load bearing members and to carry a vertical load to the building foundation through columns.

The mix design variables affecting the concrete strength which are the most critical in the strength development of concrete includes water-cementitious material ratio, total cementitious material, cement-admixture ratio, amount of super plasticizer dose .These factors are to be analyzed in order to obtain a mix for concrete of higher grade.

The design aid presently available gives design charts for design of members for concrete grade upto $F_{ck}=40N/mm^2$.Design curves for $F_y=250N/mm^2$,$415N/mm^2$ and $F_{ck}=60N/mm^2$, $F_{ck}=70N/mm^2$ using MATLAB have been drawn and given for aiding in the design of structures designed with these higher grade of concrete.

Key Words: High Performance Concrete, High Strength Concrete.

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CHAPTER 1

INTRODUCTION

CHAPTER 1. INTRODUCTION:

1.1 HIGH PERFORMANCE CONCRETE AND HIGH STRENGTH CONCRETE:

Concrete has been since long a major material for providing a stable and reliable infrastructure. Concrete with compressive strengths of 20-40 N/sqmm has been traditionally used in construction projects. With the demand for more sophisticated structural forms along with deterioration , long term poor performance of conventional concrete led to accelerated research for development of concrete which would score on all the aspects that a new construction material is evaluated upon : strength, workability, durability, affordability and will thus enable the construction of sustainable and economic buildings with an extraordinary slim design besides providing a material that will have long term better performance and reduced maintenance. The development of high performance concrete in this regard has been a great breakthrough in concrete technology. ACI defines High Performance Concrete as “Concrete meeting special combinations of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing and curing practices”. Important governing factors for High Performance Concretes are strength, long term durability, serviceability as determined by crack and deflection control, as well as response to long term environmental effects. High performance concretes (HPC) are concretes with properties or attributes which satisfy the various performance criteria. Generally, concretes with higher strengths and attributes superior to conventional concretes are called High performance concrete. Therefore High Performance Concrete can be considered as a logical development of cement concrete in which the ingredients are proportioned and selected to contribute efficiently to the various properties of cement concrete in fresh as well as in hardened states.

However, when 'high performance' is linked to structural significant behavior high performance is usually synonymous with high strength. Thus high strength concrete is basically a form of high performance concrete which has compressive strength higher than the conventional concrete. High strength concrete is specified where reduced weight is important or where architectural considerations require smaller load carrying elements .The use of high strength concrete offers numerous advantages in the sustainable and economical design of structures and gives a direct savings in the concrete volume saved ,savings in real estate costs in congested areas, reduction in form-work area and cost.

1.2 CONCEPTS IN THE DESIGN OF High Performance Concrete:

In order to achieve high strength for high performance, the various important factors that govern the strength of concrete are to be understood:

- The properties of the cement paste
- The properties of the aggregate
- The various chemical and mineral admixtures that are to be used
- The relative proportions of the constituent materials to be used .
- Paste –Aggregate interaction.
- Mixing, Compaction and Curing.
- Testing Procedures.

All these factors need to be optimized in order to obtain concrete with significantly high compressive strength for High performance concrete.

1.3 POPULARISING THE DESIGN OF STRUCTURES USING High Performance Concrete:

The use of High Performance Concrete with significantly higher compressive strength of concrete is on increasing trend in the construction industry and is being seen as an optimized solution considering the economics vis-à-vis strength and durability required for special structures. The scope of using High Performance Concrete in our constructional activities lies large, viz Multi-storied buildings, bridges and structures on coastal areas and the like. The primary reasons for selecting High Performance Concrete are to produce a more economical product, provide a feasible technical solution, or a combination of both. The use of HPC with its greater durability is likely to result in less maintenance and longer life and with the introduction of life-cycle costing, the long-term economic benefits are likely to more than offset the premium costs for initial construction. To affect this change from Conventional concrete to High Performance Concrete we will have to revive the designing of structures by encouraging use of High Performance Concrete by introducing the structural and economical advantages offered by High Performance Concrete.

CHAPTER 2

LITERATURE REVIEW

CHAPTER 2: LITERATURE REVIEW:

2.1 INTRODUCTION:

The advantages of using High Performance Concrete particularly with the structural advantages of using high strength concrete have been described in various researches. These include a reduction in member size, reduction in the self-weight and super-imposed Dead Load with the accompanying saving due to smaller foundations, reduction in form-work area and cost construction of High–rise buildings with the accompanying savings in real estate costs in congested areas, longer spans and fewer beams for the same magnitude of loading, reduced axial shortening of compression supporting members ,reduction in the number of supports and the supporting foundations due to the increase in spans ,reduction in the thickness of floor slabs and supporting beam sections which are a major component of the weight and cost of the majority of structures, superior long term service performance under static, dynamic and fatigue loading, low creep and shrinkage . Achieving high strength concrete by using various chemical and mineral admixtures is also a subject of research and different design mix methods and trial mix approaches have been proposed for the development of high strength concrete. The various parameters that govern the strength of concrete like the different constituent materials required, properties of constituent materials , proportions in which they are to be used and specifications for the production and curing technique to be used for the development of high strength concrete are also being a subject of continuous research for the development of high strength concrete which is now being seen as a logical development of concrete because of the numerous advantages that it is supposed to provide.

2.2 EARLIER RESEARCHES:

Some of the earlier studies on the effectiveness in designing of structures like high rise building With hgh strength concrete are as follows:

J. Hegger (*Aachen University of Technology, Institute of Concrete Structures, 52056, Aachen, Germany)* (1) studied the economical and constructional advantages of High-strength concrete for a 186 m high office building in Frankfurt, Germany concluded that, for columns designed for a vertical load of 20 MN with a 85 MPa-concrete more than 50 of the reinforcement can be saved compared to a 45 MPa concrete. And in spite of the approximately 60% higher concrete cost the total costs can be reduced by about 15%.

According to a study by Moreno (2), the use of 41 MPa compressive strength concrete in the lower columns of a 23-story commercial building requires a (865-mm square) column whereas the use of (83 MPa) concrete allows a reduction in column size to (610 mm square) .In addition to the reduction in initial cost, a smaller column size results in less intrusion in the lower stories of commercial space and, thereby, more rentable floor space.

Also studies have been made regarding the method for obtaining high strength concrete as regards to the constituents required, the mix design parameters, the effect of various chemical and mineral admixtures on the strength of concrete. Whilst a number of studies have considered the development of a rational or standardized method of concrete mix design for high strength concrete no widely accepted method is currently available.

S. Bhanjaa, B. Sengupta(3) on the basis of 28-day strength results have proposed modified strength water–cementitious material ratio relationships for concrete containing cement plus silica fume as a supplementary cementitious material to evaluate the strength of silica fume concrete for obtaining high strength concrete mixes.

S.C. Maiti, Raj K. Agarwal and Rajeeb Kumar (The Indian Concrete Journal * December 2006)(4) gave relationships between water-cement ratios or water cementitious materials ratios and 28-day compressive strength for concrete containing OPC or PPC or PSC or (OPC + fly ash) or (OPC + ggbs) and a superplasticiser based on data from different construction sites and gave a critical observation that these relationships are almost same as given in IS 10262 for two grades of OPC (43-grade and 53-grade). Regarding sand and water contents, suggestions to modify existing guidelines of IS 10262 have also been given for superplasticised concrete mixes.

Henry H.C. Wong and Albert K.H. Kwan (Department of Civil Engineering, The University of Hong Kong, Hong Kong) (5) introduces the concept of packing density as a fundamental principle for designing HPC mixes. The concept is based on the belief that the performance of a concrete mix can be optimized by maximising the packing densities of the aggregate particles and the cementitious materials and presents a preliminary HPC design method, called three-tier system design.

Papayianni *, G. Tsohos, N. Oikonomou, P. Mavria(Department of Civil Engineering, Aristotle University of Thessaloniki, 54 124 Thessaloniki, Greece)(6) have established the influence of superplasticizer type and mix design parameters on the performance of them in concrete mixtures for concrete of higher strength.

2.3 SCOPE OF THE PRESENT WORK:

The objective of the present work is to study the cost effectiveness of designing structures with High Performance Concrete by giving a cost comparison between concrete M20 and M60 using a concrete mix achieved in the laboratory .The effect of silica fume dosage and the dose of super plasticizer on the strength of concrete have been evaluated using an experimental programme aimed at achieving a High strength concrete mix. Design of a multi storied reinforced building has been done using both M20 and M60 using Staad Pro2004 and the differences in the quantity of concrete and steel required for different beams and columns have been calculated and analyzed and compared with respect to their cost.Design curves for M60 and M60 have also been generated using MATLAB and given in the report for use in design using the grades of concrete as the are not given in the design aid presently available.

CHAPTER 3

ACHIEVING High Performance Concrete (HPC)

CHAPTER 3: ACHIEVING High Performance Concrete (HPC):

3.1 INTRODUCTION:

The development of High Performance Concrete is based on the following well known relationships of concrete technology, for high strength, water-cement ratio should be low. The strength - w/c ratio rule holds good for concrete strength of about 100 MPa or more. Low water-cement ratio is also required for low permeability of concrete, which is vital for high durability. Impermeability is also aided by pore filling effects of fine pozzolanic additions. The relationship between coefficient of permeability of cement paste and water-cement ratio is such that the permeability increases asymptotically for water-cement ratio above 0.45 or so. Thus, low water-cement ratio ensures both high strength and low permeability, or high durability. Low water-cement ratio will require high cement content to ensure that the amounts of water and cement paste are adequate for the workability of concrete. However, too high a cement content will cause high heat of hydration and increase cracking tendency. Hence, part of the cement is to be replaced by other cementitious materials like silica fume, fly ash or ground granulated slag, or combinations thereof. Use of low water cement ratio and other cementitious materials as silica fume etc. makes use of superplasticisers mandatory. Thus, the composition of High Performance Concrete is automatically chosen -cement, aggregates, water, superplasticisers, silica fume or fly ash or slag.

3.2 COMPONENT REQUIREMENTS FOR High Performance Concrete:

CEMENT:

A high quality binder is necessary for High Performance Concrete. Cement that yields high compressive strength at the later stage is obviously preferable. The use of fine cementitious material, such as Microsilica or superfine fly ash, is useful as the fine particles grading would be extended; which would result in good filler action and reduced porosity. Furthermore, the Pozzolanic reaction with Portland cement would further strengthen the cement matrix and improve the bond strength between aggregates and the matrix. Since the cement content of high strength concrete is unavoidably high, the heat of hydration resulting from the exothermic reaction of cement with water is high. Thus it would be advantageous to use an additional cement replacement material such as ground granulated blast furnace slag or fly ash both of which are available in the local market. Furthermore, the use of such cement replacements in addition to the use of Micro silica and/or super fine ash would improve the impermeability of concrete to chlorides and sulphates; thus, the durability especially in relation to steel reinforcement corrosion protection would be improved.

COARSE AGGREGATE:

Since coarse aggregate forms the largest fraction of volume of concrete the characteristics of aggregates significantly influence the strength of concrete. The size of coarse aggregate plays an important role in determining the strength of concrete. In normal strength concrete, as size of coarse aggregate is increased, the water requirement is reduced. So the net effect is gain in strength. But in High Performance Concrete large size of coarse aggregate tend to reduce the strength .It may be attributed to smaller surface area available for bond. Cement-aggregate bond increases as aggregate particle shape changes from smooth and rounded to smooth and angular, and this must be considered for selecting the aggregate for High Performance Concrete. But trial mixtures will be the best predictor of performance. In making the trial mixtures it is important to select relatively hard and strong coarse aggregates that do not break during mixing.

FINE AGGREGATE:

The shape and surface texture of fine aggregate has a greater influence on water demand of concrete than because fine aggregates contain a much higher surface area for a given weight. Rounded and smooth fine aggregate particles are better from the view point of workability than sharp and rough particles.

CHEMICAL ADMIXTURES:

Water-cement ratio plays a vital role for achieving HPC. Reduction in water content increases the strength considerably. This can be achieved by using water reducing admixture or Super plasticizer. The use of superplasticizer generally reduces the amount of water required by 15%-40%. Super plasticizers are usually chemical compounds such as sulphonated melamine formaldehyde (SMF), sulphonated naphthalene formaldehyde (SNF), and Modified ligno sulshonates.SMF and SNF based admixtures are the most commonly used. They work by helping to disperse particles of cement when mixing water is added,which causes the cement paste to behave more like a fluid. This deflocculation of cement particles plasticize the paste to such a degree that these compounds are dubbed as “Superplasticizers”.

MINERAL ADMIXTURES:

These admixtures are generally natural or by product materials .These admixtures generally include fly ash, silica fume, ground granulated blast furnace slag. Fly ash is produced as a byproduct of combustion of pulverized coal in electric power generating plants. Silica fume is a byproduct resulting from the reduction of high purity quartz with coal in electric arc furnaces in the manufacture of silicon or ferrosilicon alloys. As the Portland cement in concrete begins to react chemically, it releases Calcium hydroxide. The silica fume reacts with this calcium hydroxide to form an additional binder called calcium silicate hydrate, which is very similar to calcium silicate hydrate formed by Portland cement. It is largely this additional binder that gives silica-fume concrete its improved hardened properties. The addition of silica fume also increases the cohesiveness, viscosity and water demand of fresh concrete. Bleeding is reduced ,allowing quicker finishing and less chance of porous transition zones between paste and aggregate.

3.3 DESIGN MIX FOR High Performance Concrete(HPC):

3.3.1 EXPERIMENTAL PROGRAMME:

The main aim of the Experimental Programme was to achieve a mix proportion for M60 in the laboratory that we can propose for further use and can be used to calculate cost aspect for the above grade of concrete. To get the control mix Entroy and Shackalock method was used. It was designed for extremely low workability. To improve the strength and workability silica fume and super plasticizers were used in trial batches. Silica fume was replaced by 5%,10% and 15%.To each percentage of silica fume replacement, superplasticizers were added in dosages of 1%,1.25% and 1.5%.Coarse aggregate was divided into three parts one retained on 5mm sieve, second part retained on 8 mm sieve and third part retained on 10 mm sieve passing 15 mm sieve.

The control mix proportion: 1 : 0.812 : 2.088

Fine aggregate /Total aggregate: 28%

Water/binder ratio=0.3

3.3.1.1 MATERIAL PROPERTIES:

Material	Specific gravity (gm/cc)
Cement	3.00
Fine aggregate	2.41
Coarse aggregate	2.63

Table 3.1. Material properties

3.3.1.2 DETAILS OF MIX-1 (Ms5) :

In this mix 5% cement was replaced by silica fume keeping the water/binder ratio same and to this, super plasticizer dosages of 1%,1.25% and 1.5% were added and the mixes were named as Ms5/1,Ms5/2,Ms5/3 respectively. So in Ms5/1, Ms5/2, Ms5/3 except super plasticizer dose all other quantities remain the same.

Mix	Cement (in kg)	Silica Fume (in kg)	Fine aggregate (in kg)	Coarse aggregate (in kg)	Super plasticizer (in kg)
Ms5/1	570.4	30.02	488.8	1257.5	6.02
Ms5/2	570.4	30.02	488.8	1257.5	7.5
Ms5/3	570.4	30.02	488.8	1257.5	9

Table3.2. Details of MIX 1(Ms5)

DETAILS OF MIX-2(Ms10):

In this mix 10% cement was replaced by silica fume keeping the water/binder ratio same and to this, super plasticizer dosages of 1%,1.25% and 1.5% were added and the mixes were named as Ms10/1, Ms10/2, Ms10/3 respectively. So in Ms10/1, Ms10/2, Ms10/3 except super plasticizer dose all other quantities remain the same.

Mix	Cement (in kg)	Silica Fume (in kg)	Fine aggregate (in kg)	Coarse aggregate (in kg)	Super plasticizer (in kg)
Ms10/1	540.4	60.04	488.8	1257.5	6.02
Ms10/2	540.4	60.04	488.8	1257.5	7.5
Ms10/3	540.4	60.04	488.8	1257.5	9

Table 3.3. Details of MIX 2(Ms10)

DETAILS OF MIX-3(Ms15):

In this mix 15% cement was replaced by silica fume keeping the water/binder ratio same and to this, super plasticizer dosages of 1%,1.25% and 1.5% were added and the mixes were named as Ms15/1, Ms15/2, Ms15/3 respectively. So in Ms15/1, Ms15/2, Ms15/3 except superplasticizer dose all other quantities remain the same.

Mix	Cement (in kg)	Silica Fume (in kg)	Fine aggregate (in kg)	Coarse aggregate (in kg)	Super plasticizer (in kg)
Ms15/1	510.4	90.07	488.8	1257.5	6.02
Ms15/2	510.4	90.07	488.8	1257.5	7.5
Ms15/3	510.4	90.07	488.8	1257.5	9

Table 3.4. Details of MIX 3(Ms15)

DETAILS OF MIX-4:

To find out the variation of slump value and compressive strength with change in water content at a constant replacement of silica fume and constant dose of superplasticizer, trial mixes were cast. The proportion for the mixes was same as above (1: 0.812 : 2.088).The cement was replaced by 10% of Silica fume. The superplasticizer dose was 1.25% of cementitious material. With this proportion the water/cementitious material ratio was varied as 0.325,.350,0.375 and the mixes were named as Ms10/1.25/1, Ms10/1.25/2 and Ms10/1.25/3 respectively .The individual components are calculated for the mixes and tabulated below.

Mix	Cement in kg	Silica fume in kg	Fine Aggregate in kg	Coarse aggregate in kg	Superplasticizer dose in kg	Water/Cementitious material ratio
Ms10/1.25/1	568	63.11	512.6	1317.5	7.88	0.325
Ms10/1.25/2	564.74	62.75	509.7	1313.6	7.84	0.35
Ms10/1.25/3	561.3	62.37	506.7	1301.8	7.79	0.375

Table 3.5. Details of MIX 4

3.3.2 RESULTS :

3.3.2.1. Measurement of Slump:

Each batch of concrete was tested for consistency immediately after mixing, by slump test as per IS : 1199-1959. The slump measured is recorded in terms of millimeters of subsidence of the specimen during the test and the following values are recorded for different trial mixes.

MIX	SLUMP VALUE (in mm)
Ms5/1	5
Ms5/2	10
Ms5/3	25
Ms10/1	4
Ms10/2	8
Ms10/3	15
Ms15/1	0
Ms15/2	3
Ms15/3	15

Table 3.6. Slump Values in mm for different mixes

3.3.2.2. Measurement of Compressive Strength of concrete at 28 days:

3.3.2.2.1 Making and Curing of Compression test specimen:

The compression test specimens are cast as per **IS : 516 – 1959.** It involves

- Sampling of Materials
- Preparation of Materials
- Proportioning
- Weighing
- Mixing Concrete
- Compacting
- Curing

3.3.2.2.2 Test for compressive strength of concrete specimen:

Compression Test specimens (150*150*150 mm) are cast using cubical moulds as per **IS : 516 – 1959** and tested for compressive strength .Three samples for each batch were tested and the results obtained are as follows:

MIX	28 days compressive strength(N/sqmm)
Ms5/1	60.1
Ms5/2	54.3
Ms5/3	51.2
Ms10/1	45.4
Ms10/2	51.1
Ms10/3	51.8
Ms15/1	47.3
Ms15/2	41.9
Ms15/3	45.2

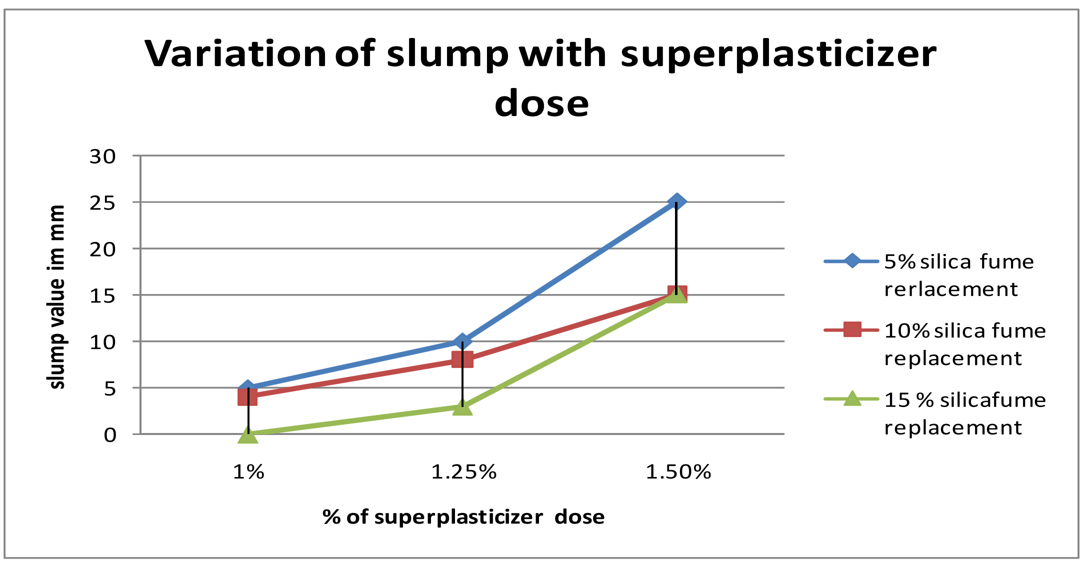
Table 3.7. Compressive strengths for MIX1,MIX2,MIX3

Mix	W/CM ratio	28 days compressive strength in N/sqmm
Ms10/1.25/0	0.3	51
Ms10/1.25/1	0.325	38.67
Ms10/1.25/2	0.35	37.33
Ms10/1.25/3	0.375	36.74

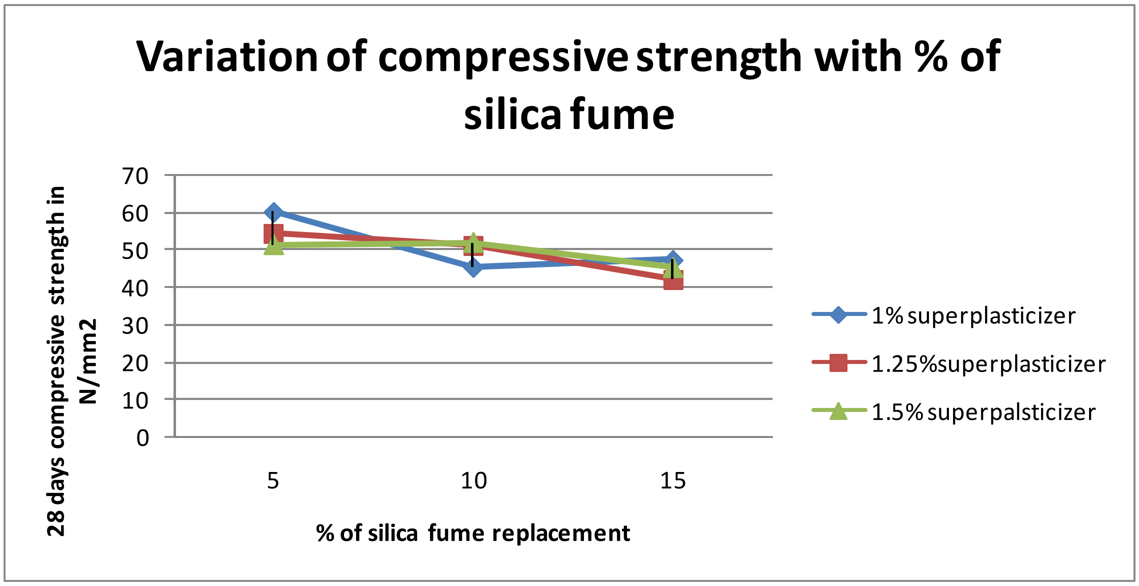
Table 3.8. Compressive strengths for MIX 4

3.3.3 ANALYSIS OF RESULTS:

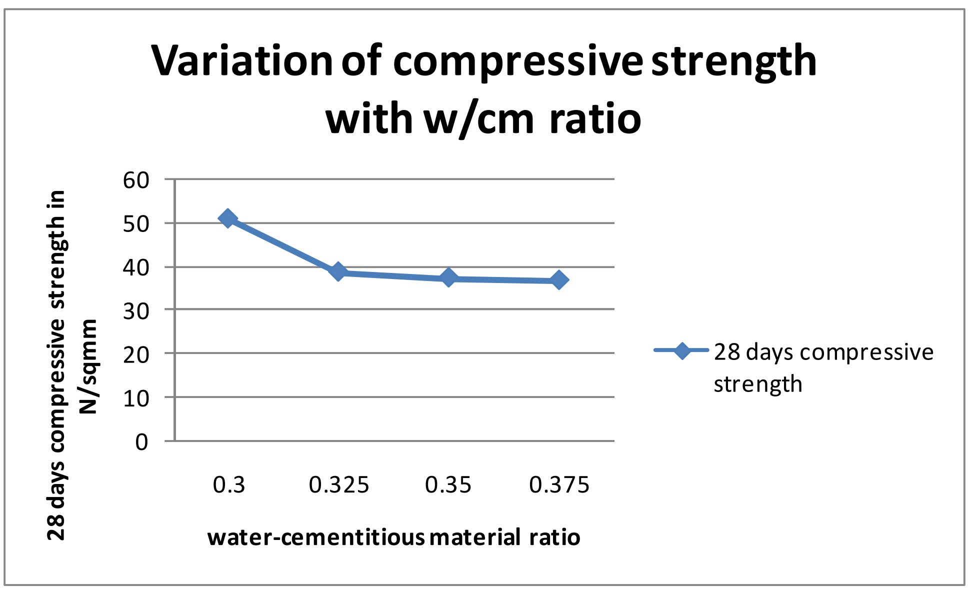
The variation of slump with superplasticizer content and the compressive strength variation with the silica fume replacement was observed with the following graphs:



Graph 3.1.Variation of Slump with Super plasticizer dose



Graph 3.2. Variation of compressive strength with % replacement of silica fume



Graph 3.3: Variation of compressive strength with W/CM ratio

3.2.4 CONCLUSION:

The mix design variables affecting the concrete strength which are the most critical in the strength development of concrete including water-cementitious material ratio, total cementitious material, cement-admixture ratio amount of super plasticizer dose are to be analyzed and optimum values of the critical mix design variables are to be taken for obtaining the mix design for the required High Performance Concrete.

CHAPTER 4

STUDY OF COST EFFECTIVENESS

CHAPTER 4: STUDY OF COST EFFECTIVENESS

4.1 COST CALCULATION AND COMPARISION FOR M20 AND M60:

The cost calculation for concrete M20 and M60 was done and found out to be:

Details of cost of 10 Cum of cement concrete(M60): 1: 0.812 : 2.088						
Materials	Unit	Quantity/Nos			Rate	Cost
Stone aggr	Cum	4.78			765.7	3660.046
sand	Cum	2.03			89.34	181.3602
cement	Quintal	57			360	20520
silica fume	kg	300.25			30	9007.5
Superplast	kg	60.24			50	3012
				Total cost per 10cum		36380.91
				Total cost per cum		3638.091

Table 4.1.Cost calculation for M60

Details of cost of 10 Cum of cement concrete(M20): 1:1.5:3						
Materials	Unit	Quantity/Nos			Rate	Cost
Stone aggr	Cum	8.52			765.7	6523.764
sand	Cum	4.41			89.34	393.9894
cement	Quintal	40			360	14400
				Total cost per 10 cum		21317.75
				Total cost per cum		2131.775

Table 4.2.Cost Calculation for M20

4.2 DESIGN OF A REINFORCED CONCRETE BUILDIND FRAME USING M20 AND M60 AND COMPARISION

4.2.1 INTRODUCTION:

A reinforced concrete building frame which was taken to be a library building has been analyzed and designed using Staad.Pro 2004 using concrete of grade M20 and M60 and has been compared as regards to the beam and column concrete consumption, steel reinforcement required and the cost aspect for concrete consumption and steel reinforcement required.

4.2.2 ANALYSIS DESIGN USING StaadPro 2004:

4.2.2.1 CREATING THE MODEL:

The model of the Reinforced concrete building frame was created using the graphical model generation mode, or graphical user interface (GUI).

Load Data for the building:

1.Dead Load

(a) Finishes=2.5 KN/sqm

Floor Finishes=1.0 KN/sqm

(b) Slab=25 D KN/sqm where D is the depth of the slab

(c) Walls=External 250 mm thick =20*.25=5 KN/m/ m height

Internal Walls=150 mm thick=20*.15=3KN/m/m height

2.Live Load (a) Roof=1.5 KN/sqm

(b) Library=10KN/sqm

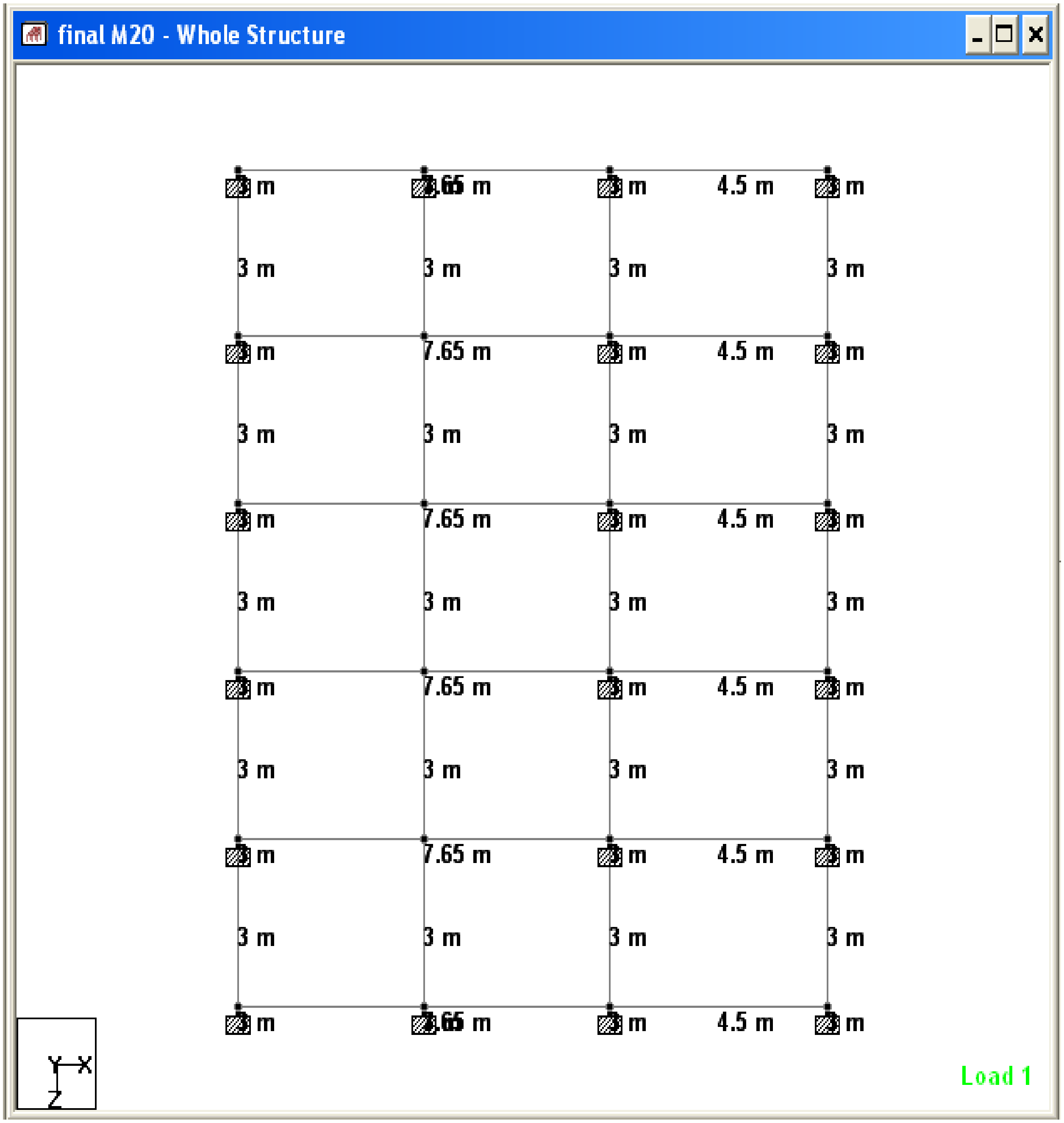


Fig 4.1 Key Plan of slab beam of the building

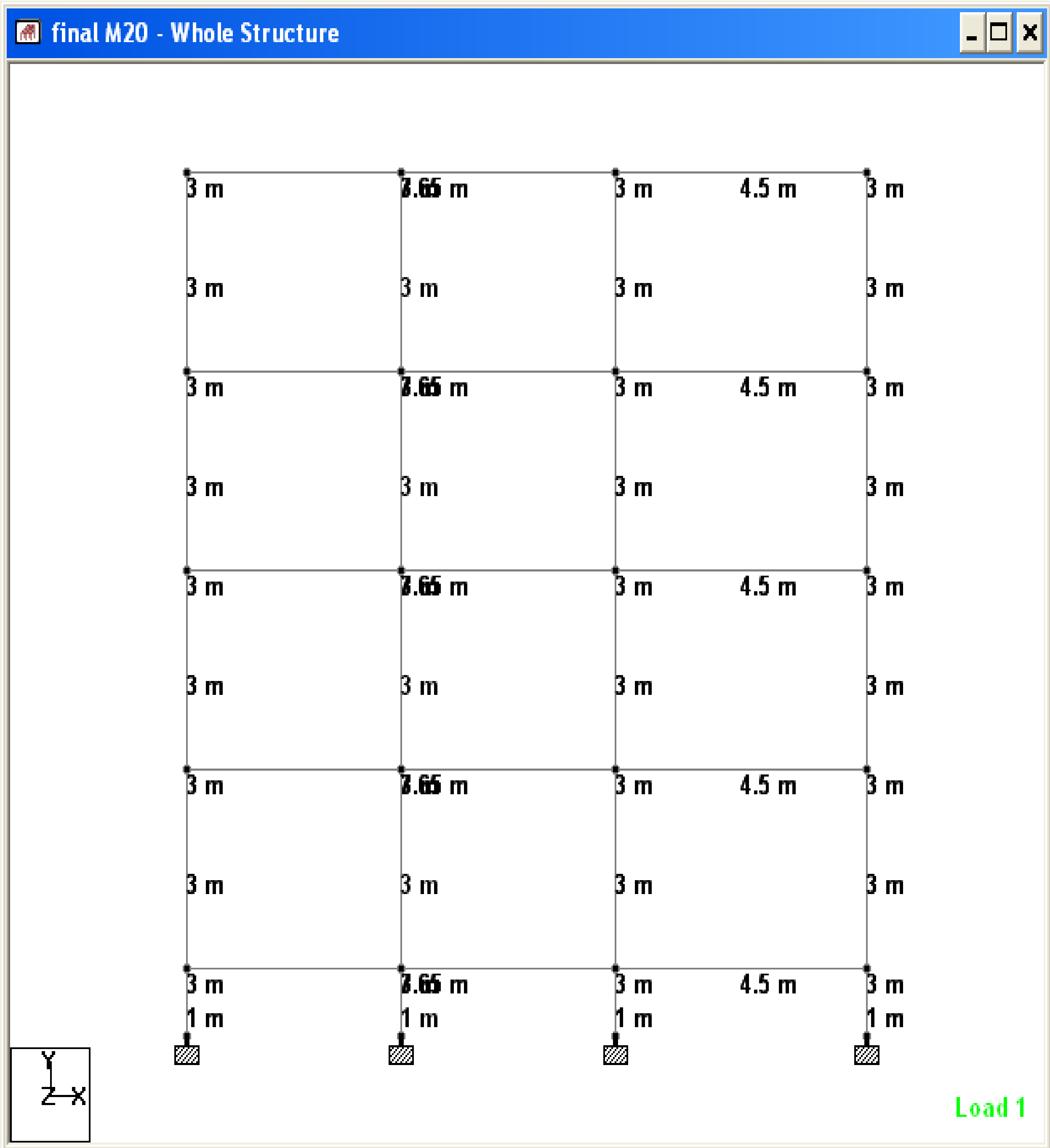


Fig 4.2 Front View of The Building

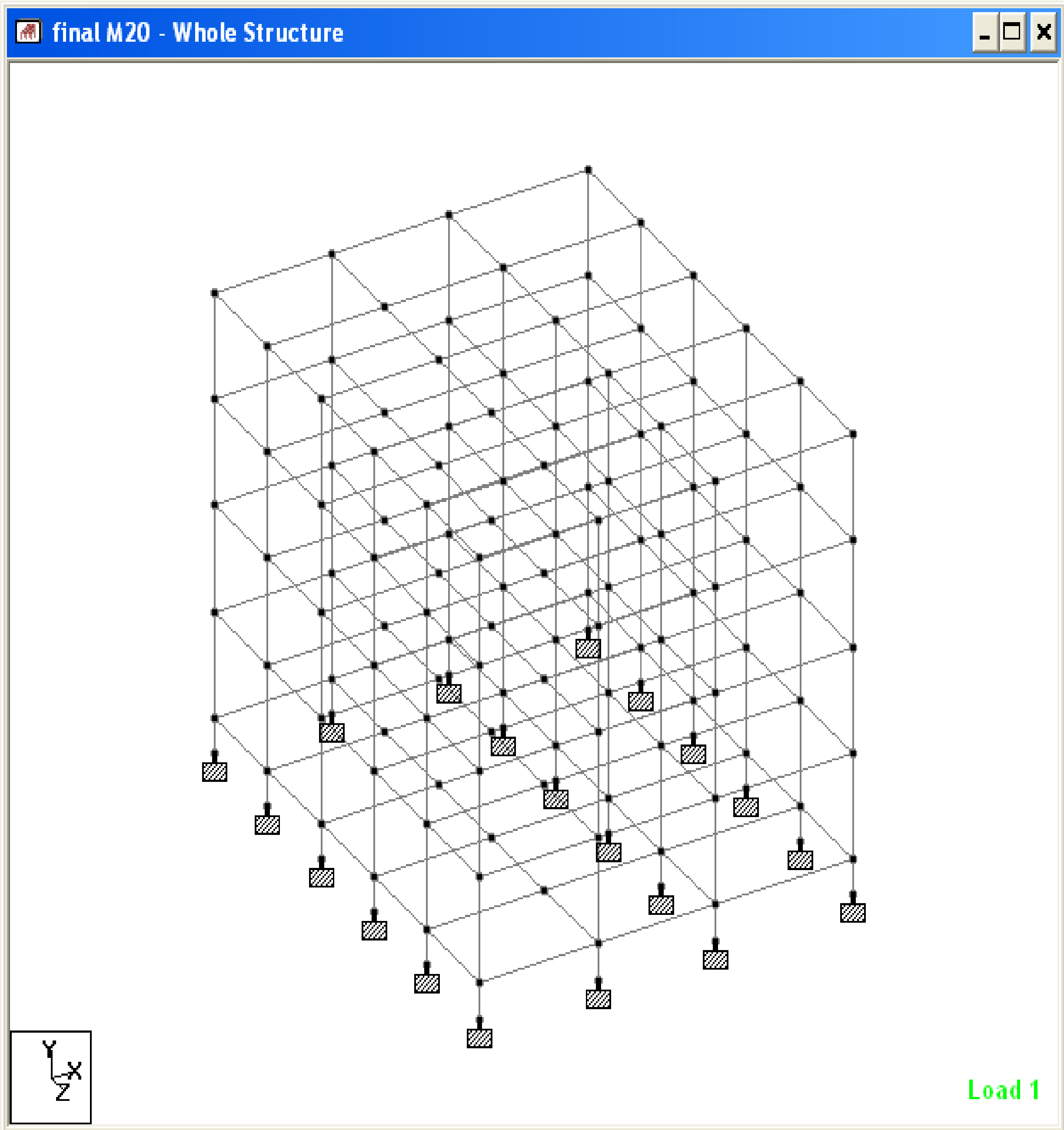


Fig 4.3 Model of the building

4.2.2.2 Generation of member property:

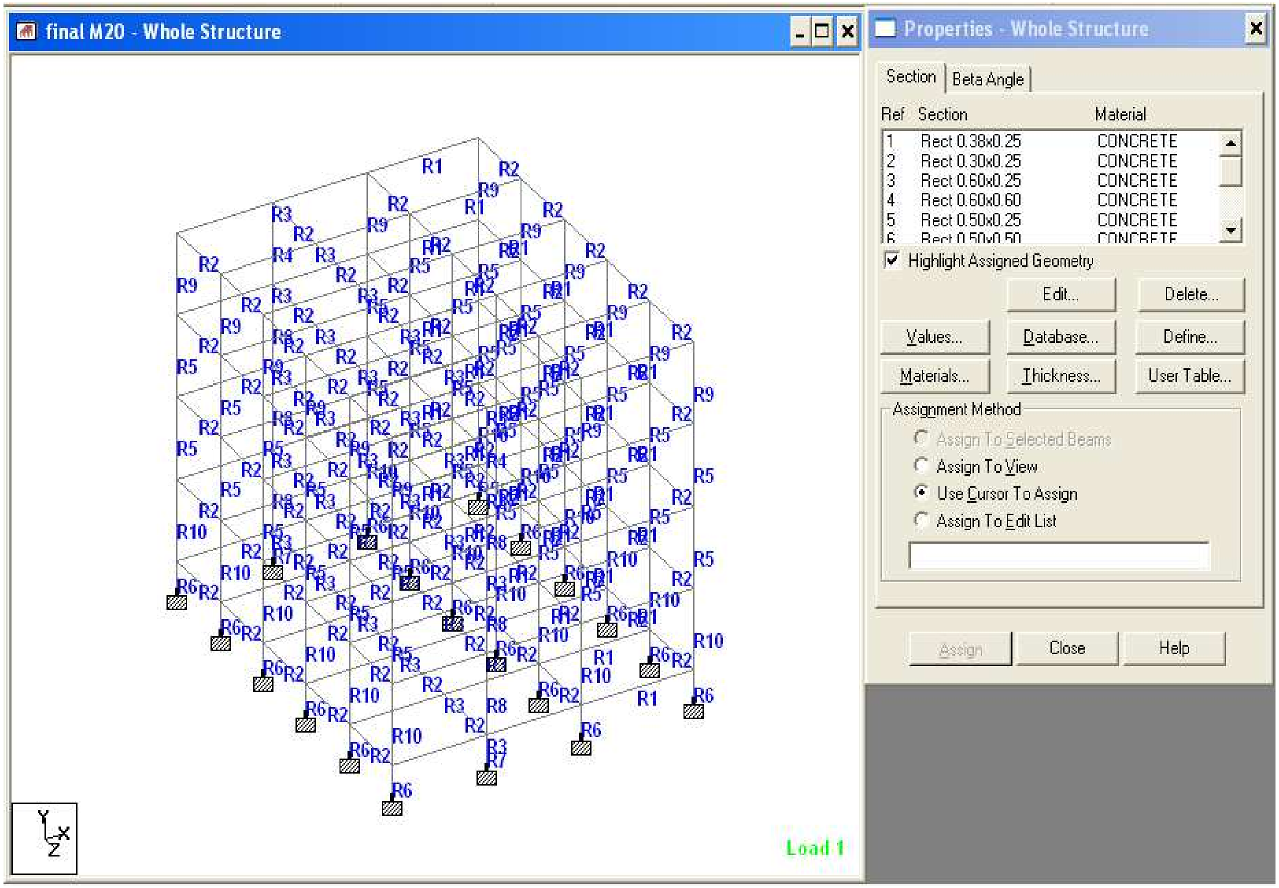


Fig 4.4 Generation of member property

R1 = 375mm*250mm
R2= 300mm*250mm
R3=600mm*250mm
R4=600mm*600mm
R5=500mm*250mm
R6=500mm*500mm
R7=600mm*600mm
R8=500mm*500mm
R9=350mm*250mm
R10=450mm*450mm

4.2.2.3 Materials for the structure:

The materials for the structure were specified as concrete with their various constants as per standard IS code of practice.

4.2.2.4 Supports

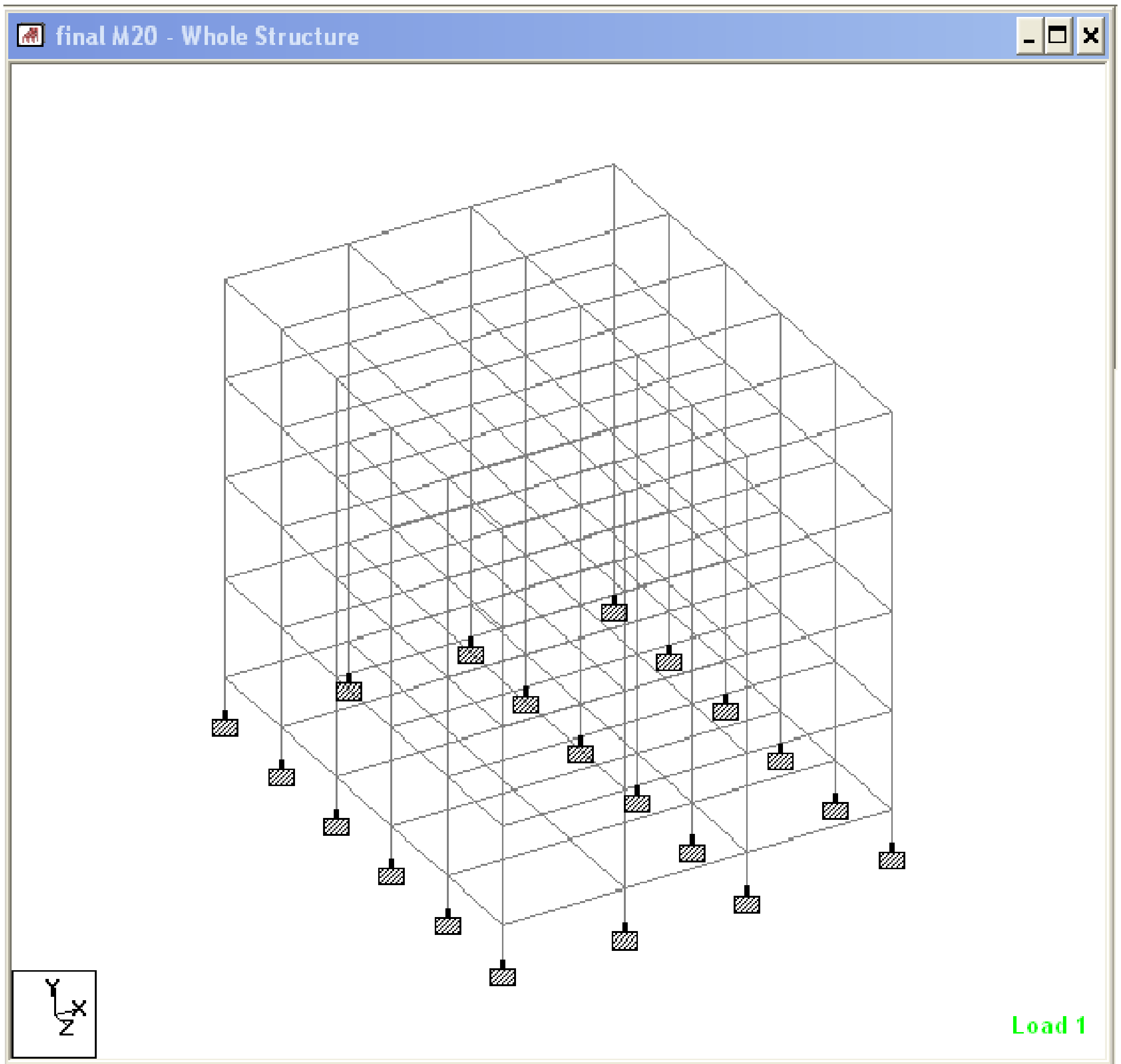


Fig 4.5 Supports

4.2.2.5 Loading:

The frame was analyzed under a repeat load of 1.5 Dead Load + 1.2 Live Load.

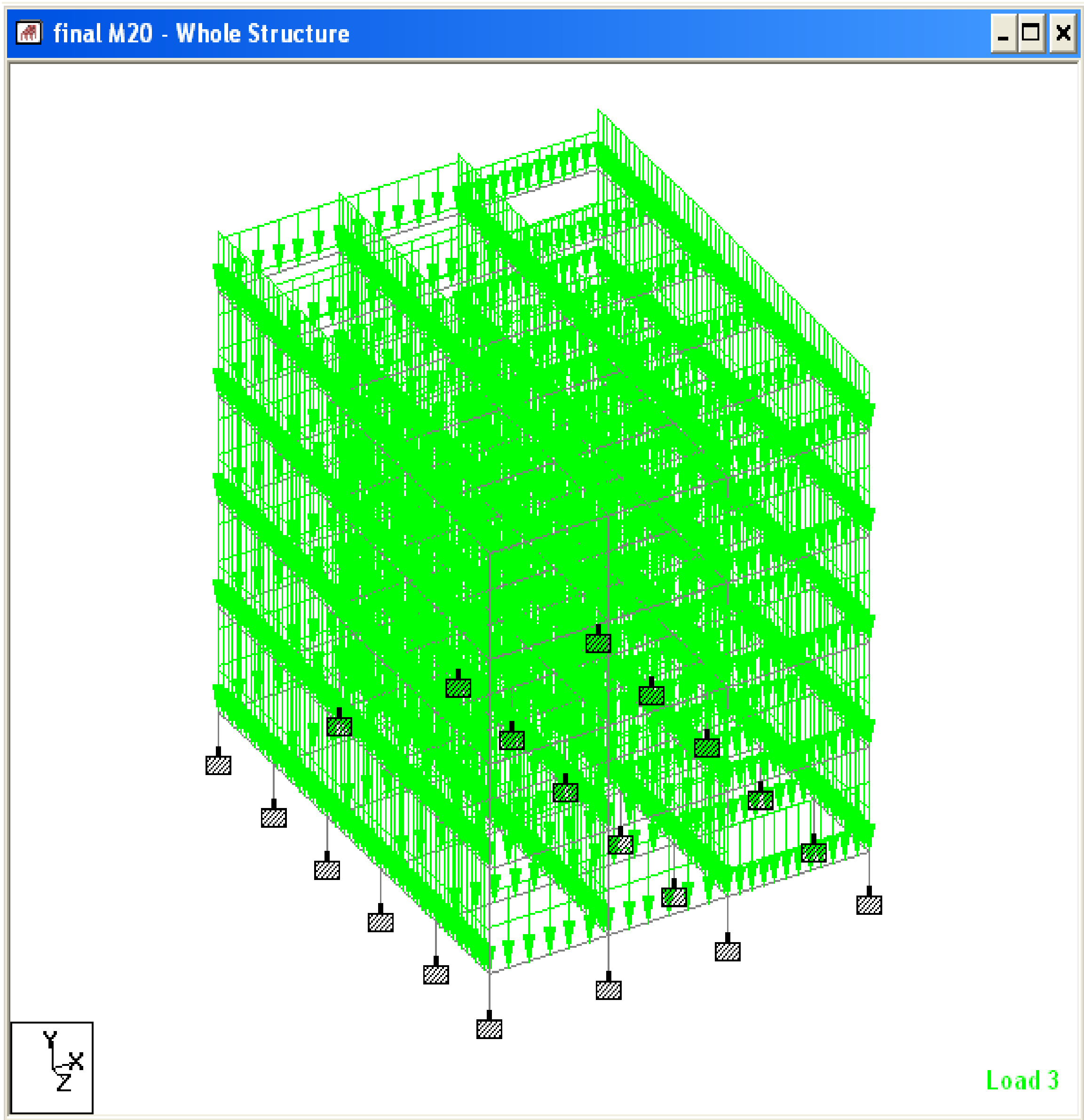


Fig 4.6 Loading

4.2.2.6 Design Specifications:

The structure was designed for concrete in accordance with IS code. The parameters such as clear cover, Fy, Fc, etc were specified. Then it has to be specified which members are to be designed as beams and which member are to be designed as columns.The specification for grade of concrete was first taken as Fc=20 N/sqmm for case 1. and then it was changed to be Fc=60 N/sqmm was taken in case 2 and then Fc=60N/sqmm with reduced section were taken in case 3.

4.2.2.7 Analysis and design results:

Two beams , Beam no 109 and Beam no.132 and column no.177 were analysed .Beam no.109 forms the beam B2 at exterior roof level at the second floor. Beam no 132 forms the beam B1 at the exterior roof level of the second floor whereas the Column no.177 forms the column of second floor were analyzed and the reinforcement required were obtained.

4.2.2.7.1

Case 1.Design Using M20

```
=======================================================================

C O L U M N  N O.   177 D E S I G N  R E S U L T S
M20             Fe415 (Main)          Fe415 (Sec.)
LENGTH:  3000.0 mm   CROSS SECTION:  250.0 mm X  500.0 mm  COVER: 40.0 mm
DESIGN FORCES (KNS-MET)
DESIGN AXIAL FORCE (Pu)  :   252.1
TOTAL DESIGN MOMENTS   :   40.82        27.16
REQD STEEL AREA   :    904.46 Sq.mm.
=================================================================
```

==

B E A M N O.   132 D E S I G N R E S U L T S

M20   Fe415 (Main)   Fe415 (Sec.)

LENGTH: 7650.0 mm   SIZE: 250.0 mm X 600.0 mm   COVER: 25.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

SECTION	0.0 mm	1912.5 mm	3825.0 mm	5737.5 mm	7650.0 mm
TOP	1295.36	0.00	0.00	0.00	1421.61
REINF.	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)
BOTTOM	0.00	380.93	939.69	323.65	79.29
REINF.	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)

==

==

B E A M N O.   109 D E S I G N R E S U L T S

M20   Fe415 (Main)   Fe415 (Sec.)

LENGTH: 4500.0 mm   SIZE: 250.0 mm X 375.0 mm   COVER: 25.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

SECTION	0.0 mm	1125.0 mm	2250.0 mm	3375.0 mm	4500.0 mm
TOP	524.91	0.00	0.00	176.66	878.86
REINF.	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)
BOTTOM	0.00	176.66	262.44	176.66	74.87
REINF.	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)

==

4.2.2.7.2

Case 2. Design Using M60:

==

C O L U M N   N O.   177 D E S I G N   R E S U L T S

M60 Fe415 (Main) Fe415 (Sec.)

LENGTH: 3000.0 mm CROSS SECTION: 250.0 mm X 500.0 mm COVER: 40.0 mm

DESIGN FORCES (KNS-MET)

DESIGN AXIAL FORCE (Pu): 252.1

TOTAL DESIGN MOMENTS : 40.82 27.16

REQD. STEEL AREA : 519.93 Sq.mm.

B E A M N O.   132 D E S I G N R E S U L T S

M60 Fe415 (Main) Fe415 (Sec.)

LENGTH: 7650.0 mm SIZE: 250.0 mm X 600.0 mm COVER: 25.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

SECTION	0.0 mm	1912.5 mm	3825.0 mm	5737.5 mm	7650.0 mm
TOP REINF.	1116.62 (Sq. mm)	0.00 (Sq. mm)	0.00 (Sq. mm)	0.00 (Sq. mm)	1238.01 (Sq. mm)
BOTTOM REINF.	0.00 (Sq. mm)	362.76 (Sq. mm)	854.88 (Sq. mm)	310.17 (Sq. mm)	0.00 (Sq. mm)

==

B E A M N O.   109 D E S I G N R E S U L T S

M60   Fe415 (Main)   Fe415 (Sec.)

LENGTH: 4500.0 mm   SIZE: 250.0 mm X 375.0 mm   COVER: 25.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

SECTION	0.0 mm	1125.0 mm	2250.0 mm	3375.0 mm	4500.0 mm
TOP	480.31	0.00	0.00	176.66	765.58
REINF.	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)
BOTTOM	0.00	176.66	250.86	176.66	0.00
REINF.	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)

4.2.2.7.3

Case 3. Design with M60 and reduced sections

===

C O L U M N N O.   177 D E S I G N R E S U L T S

M60   Fe415 (Main)   Fe415 (Sec.)

LENGTH: 3000.0 mm   CROSS SECTION: 250.0 mm X 450.0 mm COVER: 40.0 mm

DESIGN FORCES (KNS-MET)

DESIGN AXIAL FORCE (Pu)   : 247.1

TOTAL DESIGN MOMENTS   : 39.89   26.90

REQD. STEEL AREA : 605.66 Sq.mm.

===

===

B E A M N O.   132 D E S I G N R E S U L T S

M60   Fe415 (Main)   Fe415 (Sec.)

LENGTH: 7650.0 mm SIZE: 250.0 mm X 550.0 mm COVER: 25.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

SECTION	0.0 mm	1912.5 mm	3825.0 mm	5737.5 mm	7650.0 mm
TOP	1290.49	0.00	0.00	0.00	1422.24
REINF.	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)
BOTTOM	0.00	359.24	897.27	302.33	0.00
REINF.	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)

B E A M N O. 109 D E S I G N R E S U L T S

M60 Fe415 (Main) Fe415 (Sec.)

LENGTH: 4500.0 mm SIZE: 250.0 mm X 350.0 mm COVER: 25.0 mm

SUMMARY OF REINF. AREA (Sq.mm)

SECTION	0.0 mm	1125.0 mm	2250.0 mm	3375.0 mm	4500.0 mm
TOP	531.46	0.00	0.00	163.86	790.30
REINF.	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)
BOTTOM	0.00	163.86	277.35	163.86	0.00
REINF.	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)	(Sq. mm)

4.2.2.7.4

Column section(250*500) with Grades M50,M60,M70,M80,M90,M100

C O L U M N N O. 259 D E S I G N R E S U L T S
M20 Fe415 (Main) Fe415 (Sec.)
LENGTH: 3000.0 mm CROSS SECTION: 250.0 mm X 500.0 mm
COVER: 40.0 mm

DESIGN FORCES (KNS-MET)
DESIGN AXIAL FORCE (Pu) : 585.3

TOTAL DESIGN MOMENTS : 104.92 33.54

REQD. STEEL AREA : 2047.36 Sq.mm.
==
==

C O L U M N N O. 259 D E S I G N R E S U L T S
M50 Fe415 (Main) Fe415 (Sec.)
LENGTH: 3000.0 mm CROSS SECTION: 250.0 mm X 500.0 mm COVER: 40.0 mm
DESIGN FORCES (KNS-MET)
DESIGN AXIAL FORCE (Pu) : 585.3

TOTAL DESIGN MOMENTS : 104.92 34.37

REQD. STEEL AREA : 1049.64 Sq.mm.

==

C O L U M N N O. 259 D E S I G N R E S U L T S
M60 Fe415 (Main) Fe415 (Sec.)
LENGTH: 3000.0 mm CROSS SECTION: 250.0 mm X 500.0 mm COVER: 40.0 mm
DESIGN FORCES (KNS-MET)
DESIGN AXIAL FORCE (Pu) : 585.3

TOTAL DESIGN MOMENTS : 104.92 34.37

REQD. STEEL AREA : 892.20 Sq.mm.
==
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C O L U M N N O. 259 D E S I G N R E S U L T S
M70 Fe415 (Main) Fe415 (Sec.)
LENGTH: 3000.0 mm CROSS SECTION: 250.0 mm X 500.0 mm COVER: 40.0 mm
DESIGN FORCES (KNS-MET)
DESIGN AXIAL FORCE (Pu) : 585.3

TOTAL DESIGN MOMENTS : 104.92 34.37

REQD. STEEL AREA : 794.73 Sq.mm.
==\
===

C O L U M N N O. 259 D E S I G N R E S U L T S
M80 Fe415 (Main) Fe415 (Sec.)
LENGTH: 3000.0 mm CROSS SECTION: 250.0 mm X 500.0 mm COVER: 40.0 mm
DESIGN FORCES (KNS-MET)
DESIGN AXIAL FORCE (Pu) : 585.3

TOTAL DESIGN MOMENTS : 104.92 34.37

REQD. STEEL AREA : 721.63 Sq.mm.

==
==

C O L U M N N O. 259 D E S I G N R E S U L T S
M90 Fe415 (Main) Fe415 (Sec.)
LENGTH: 3000.0 mm CROSS SECTION: 250.0 mm X 500.0 mm COVER: 40.0 mm
DESIGN FORCES (KNS-MET)
DESIGN AXIAL FORCE (Pu) : 585.3

TOTAL DESIGN MOMENTS : 104.92 34.37

REQD. STEEL AREA : 676.44 Sq.mm.

==
== C O L
C O L U M N N O. 259 D E S I G N R E S U L T S
M100 Fe415 (Main) Fe415 (Sec.)
LENGTH: 3000.0 mm CROSS SECTION: 250.0 mm X 500.0 mm COVER: 40.0 mm
DESIGN FORCES (KNS-MET)
DESIGN AXIAL FORCE (Pu) : 585.3

TOTAL DESIGN MOMENTS : 104.92 34.37

REQD. STEEL AREA : 629.79 Sq.mm.
==

4.2.2.8 Comparisons of the results

4.2.2.8.1 Comparison in concrete and reinforcement required

For column no.177:

1. M20 and (250*500) section

   A_{st} required =904.46 mm²

2. M60 and (250*500) section

A_{st} required =519.93 mm²

3. M60 and (250*450) section

   A_{st} required =605.66 mm²

Difference in steel requirement between 1 and 2=384.53 mm² .

Difference in steel requirement between 1 and 3=298.8 mm² .

Difference in concrete requirement between 1 and 3 per m=.0125 cum.

For beam no 109 :

1. M20 and (250*375) section

   A_{st} required = 2271.03 mm²

2. M60 and (250*375) section

   A_{st} required =2026.73 mm²

3. M60 and (250*350) section

   A_{st} required =2090.69 mm²

Difference in steel requirement between 1 and 2=244.3mm²

Difference in steel requirement between 1 and 3= 180.34 mm²

Difference in concrete requirement between 1 and 3 per m= .00625 cum

For beam no.132

1. M20 and (250*600) section

   A_{st} required =4440.53 mm²

2. M60 and (250*600) section

   A_{st} required = 3882.44 mm²

3. M60 and (250*550) section

   A_{st} required = 4271.57 mm²

Difference in steel requirement between 1 and 2=558.090 mm²

Difference in steel requirement between 1 and 3=168.960 mm²

Difference in concrete requirement between 1 and 3 per m=.0125 cum

4.2.2.8.2Cost Comparison:

Case 1 : (a)Beams and columns designed using M20:

************** CONCRETE TAKE OFF **************	
(FOR BEAMS AND COLUMNS DESIGNED	M20)
TOTAL VOLUME OF CONCRETE = 105.01 CU.METER	
BAR DIA	WEIGHT
(in mm)	(in New)
--------	--------
8	25757.25
10	7067.31
12	21867.72
16	12128.28
20	48254.73
25	10003.06

*** TOTAL=	125078.35

Table 4.3 Concrete and steel requirement for beams and columns using M20

Case 1 : (b)Beams and columns designed using M60:

************** CONCRETE TAKE OFF **************	
(FOR BEAMS AND COLUMNS DESIGNED USING M60)	
TOTAL VOLUME OF CONCRETE = 105.01 CU.METER	
BAR DIA	WEIGHT
(in mm)	(in New)
--------	--------
8	26132.00
10	12145.68
12	21411.84
16	14008.50
20	18511.27
25	2313.20

*** TOTAL=	94522.48

Table 4.4 Concrete and steel requirement for beams and columns using M60

Cost of concrete and steel reinforcement in case 1 (a) =(105.01*2131.775) +(12507.835*50)
= Rs 849249.4428

Cost of concrete and steel reinforcement in case 1 (b) =(105.01*3638.091) + (9452.248*50)
= Rs 854648.335

Difference in Cost Between Case 1 (a) and Case 1 (b) = Rs 5398.89311

Increase in Cost = 0.6% with high strength concrete

Case 2(a):Columns designed using M20

************** CONCRETE TAKE OFF **************	
(FOR COLUMNS DESIGNED USING M20)	
TOTAL VOLUME OF CONCRETE = 41.09CU.METER	
BAR DIA	WEIGHT
(in mm)	(in New)
--------	--------
8	5936.43
12	15846.64
16	6813.58
20	31347.51
25	302.38

*** TOTAL=	60246.55

Table 4.5 Concrete and steel requirement for columns using M20

Case 2(b):Columns designed using M60:

************** CONCRETE TAKE OFF **************	
(FOR COLUMNS DESIGNED USING M60)	
TOTAL VOLUME OF CONCRETE =	41.09 CU.METER
BAR DIA	WEIGHT
(in mm)	(in New)
--------	--------
8	6277.90
12	13826.64
16	5822.52
20	15673.75

*** TOTAL=	41600.82

Table 4.6 Concrete and steel requirement for columns using M60

Cost of concrete and steel reinforcement in Case 2(a) = (41.09*2131.775)+(6024.655*50)
=Rs 388827.3848

Cost of concrete and steel reinforcement in Case 2(b) = (41.09*3638.091)+(4160.082*50)
=Rs 357493.2592

Cost difference between Case 2(a) and Case 2(b) = Rs 31334.1256

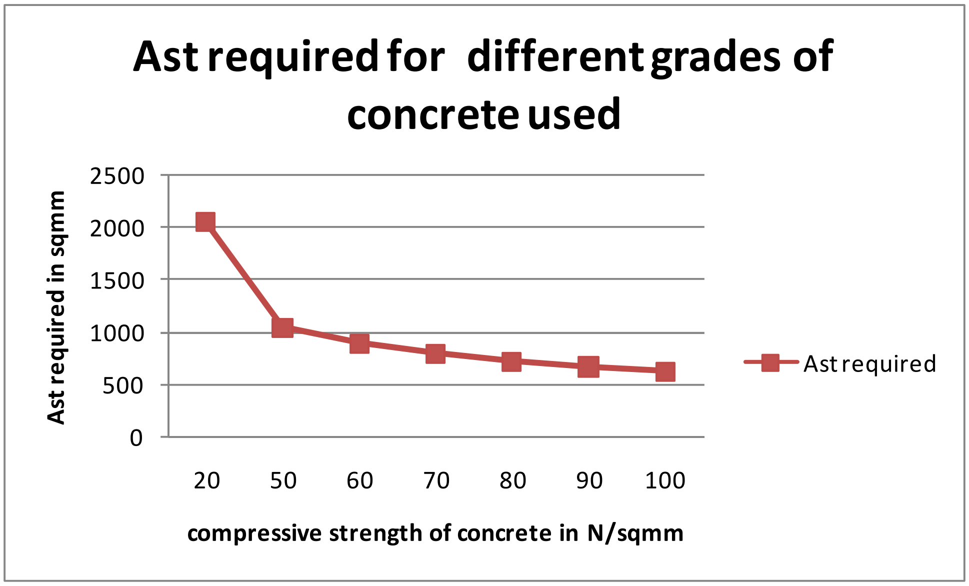
Savings = 8% on the previous cost.

4.2.2.8.3

The column no.259 is designed for concrete with compressive strength of 50 N/sqmm,60 N/sqmm,70 N/sqmm,80 N/sqmm,90 N/sqmm,100 N/sqmm respectively using the same column section of (250*500 mm) and the steel area required is found out .The steel areas required for column is found to reduce with a corresponding increase in the strength of concrete used.

Fc (N/sqmm)	Ast required in sqmm
20	2047
50	1050
60	892
70	795
80	722
90	676
100	630

Table 4.7. Ast required for columns with high strength concrete



Graph 4.1. Variation of steel area required with increase in the strength of concrete to be used

4.3 CONCLUSION:

At the present time, a cubic metre of High Performance Concrete is found to be more than a cubic metre of conventional concrete. High Performance Concrete requires additional quantities of materials such as cement, silica fume, high-range water-reducers to ensure that the concrete meets the specified strength and performance which increase the cost of High Performance Concrete. But overall the use of concrete with higher compressive strengths offer economically viable solution in columns and other load bearing members Also the use of High Performance Concrete with concrete compressive strength higher than conventional concrete is found to offer structural advantages viz, more efficient floor plans through smaller vertical members (columns) and also proves to be the most economical alternative by reducing both the total volume of concrete and the amount of steel required for a load bearing member besides providing resistance to long term deteoriation ,lower maintenance etc.

CHAPTER 5

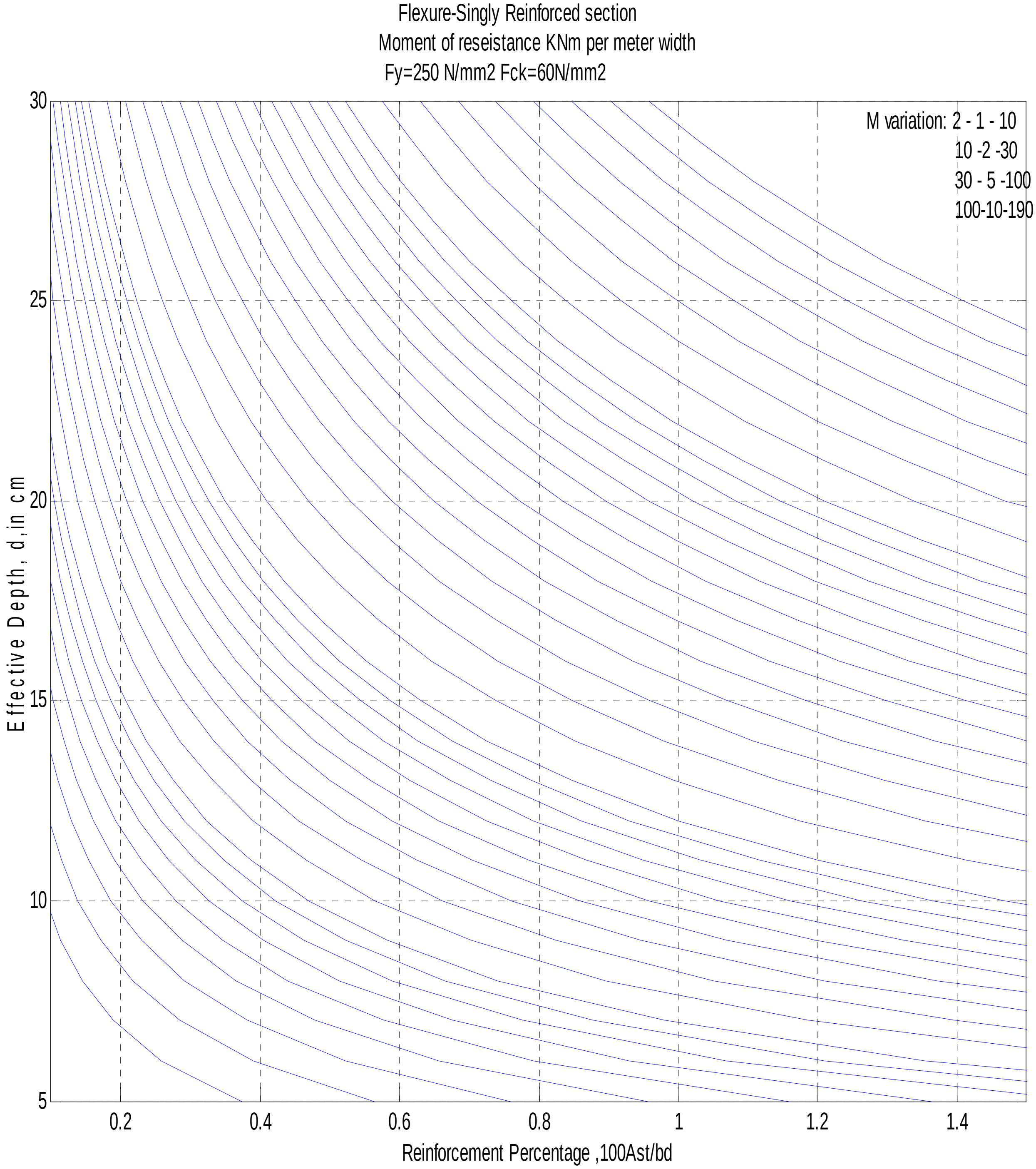
DESIGNING WITH High Performance Concrete (HPC)

CHAPTER 5: DESIGNING WITH High Performance Concrete(HPC):

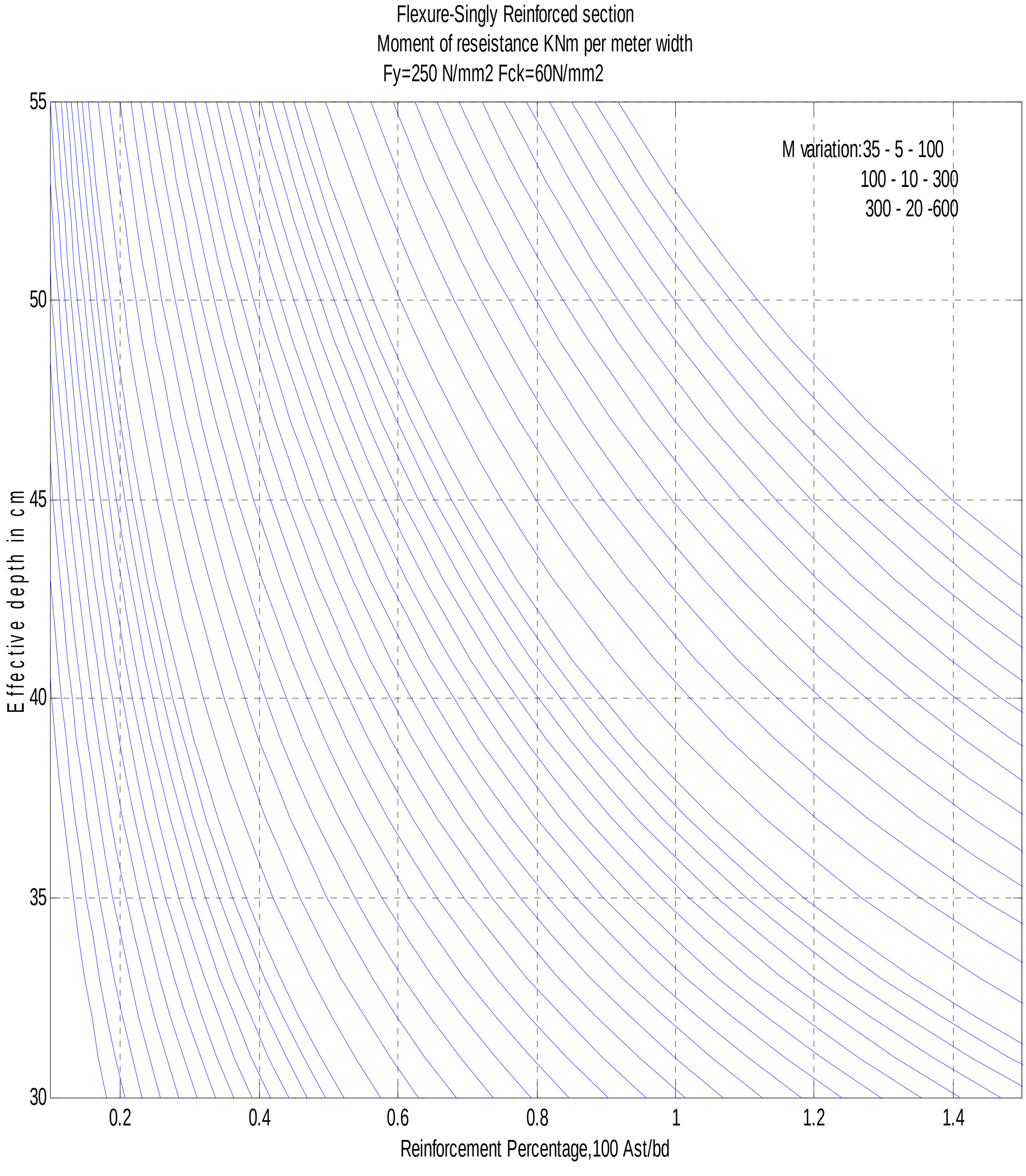
"Design Aids For Reinforced Concrete to IS: 456-1978" play a very important role in designing the structural members. In currently available Design Aid for Flexural Members design curves for $F_{ck}=15N/mm^2$ and $F_{ck}=20N/mm^2$ are available .For popularising the use of M60 and M70 we have drawn the design curves for $F_y=250N/mm^2$,$415N/mm^2$ and $F_{ck}=60N/mm^2$,$F_{ck}=70N/mm^2$ using MATLAB. The design curves are prepared by assigning different values to Mu/b and plotting d *versus* Pt. The Design curves are given in the subsequent pages.

In the graphs Moment of Resistance (M) variation has been shown on the right top corner.

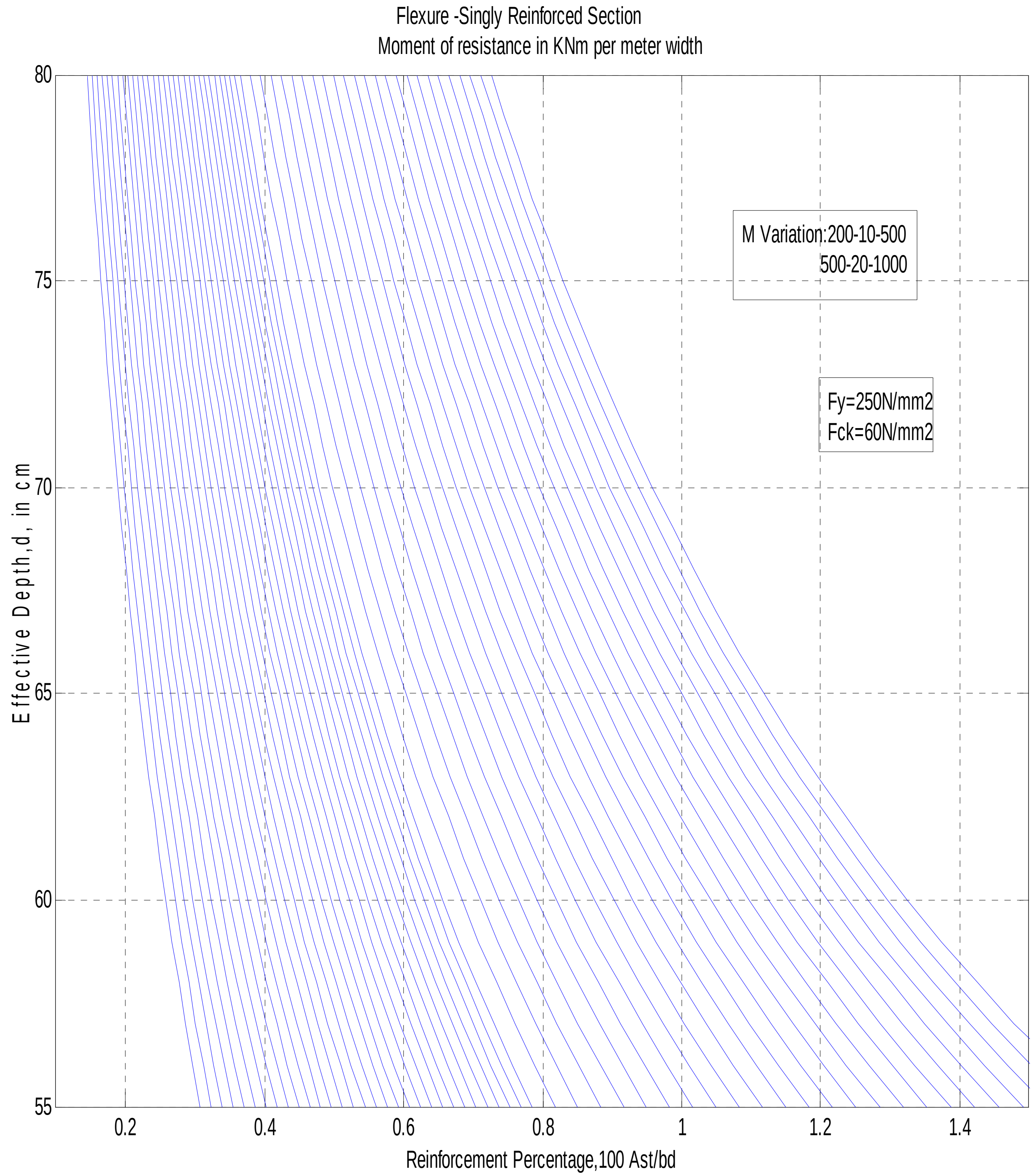
M variation:"2-1-10 "denotes the variation of M from 2 KNm to 10 KNm in steps of 1 KNm



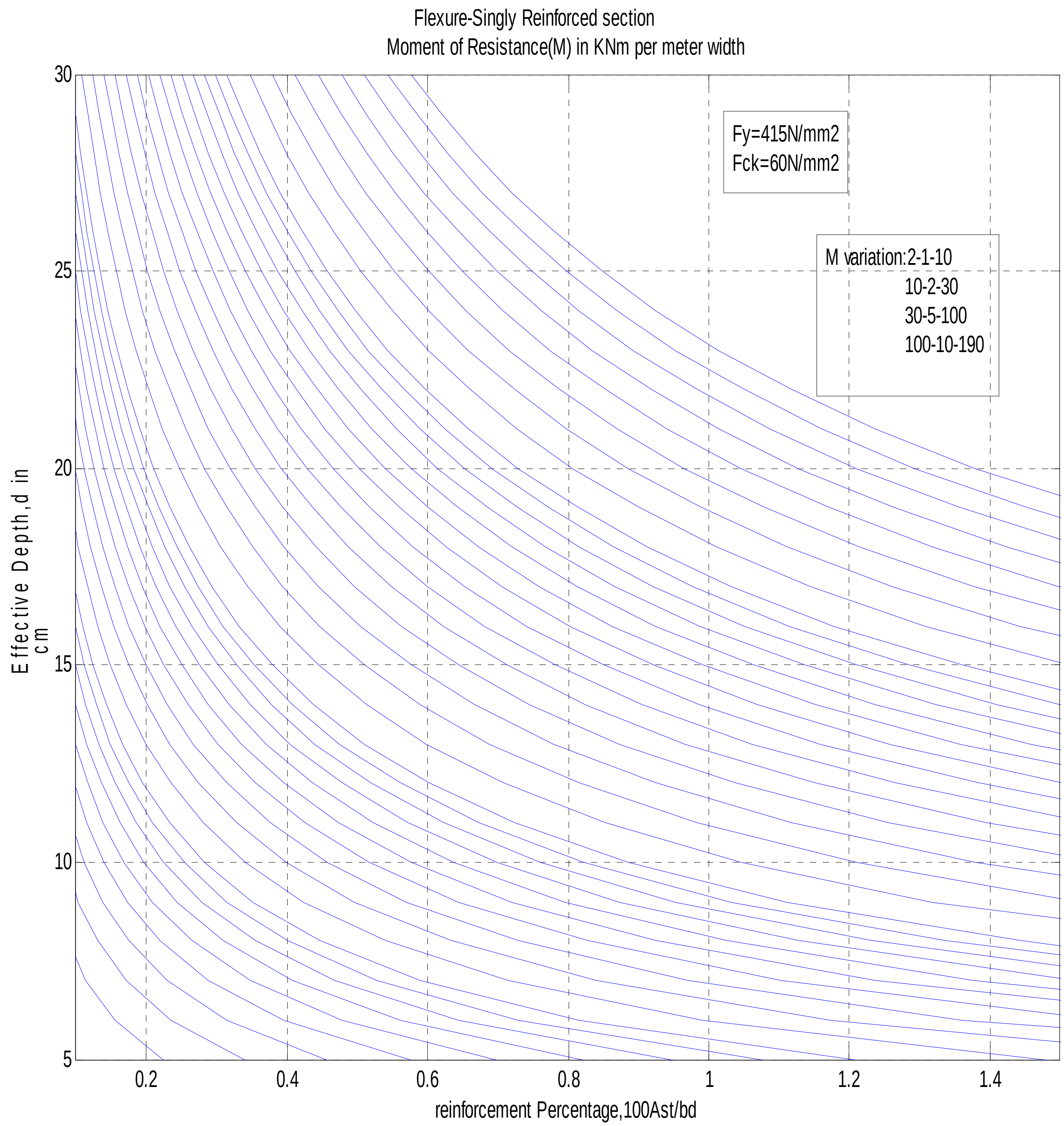
Graph 5.1 Design Curve for Singly Reinforced section in Flexure for Fy=250 N/sqmm and Fc=60 N/sqmm



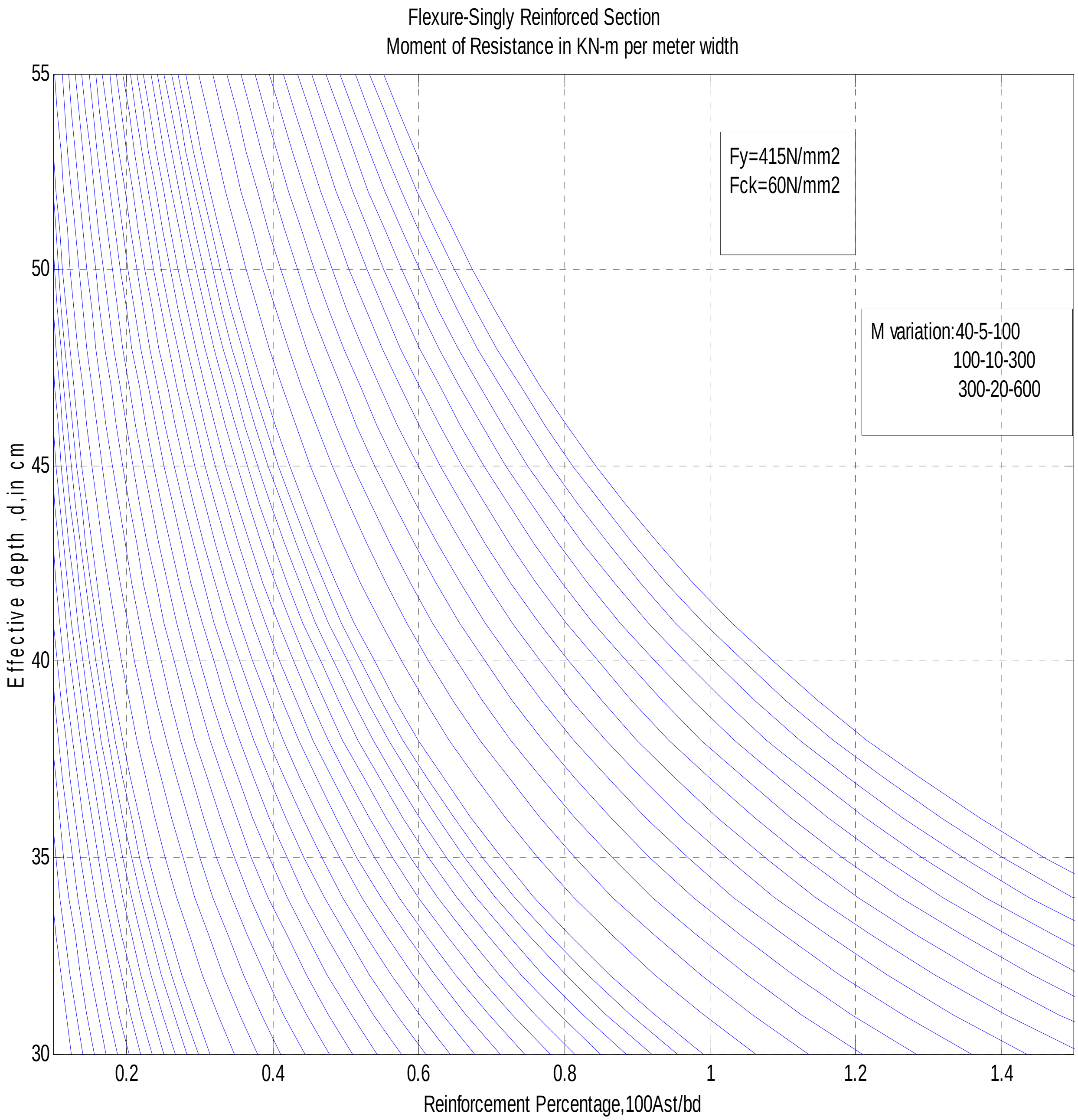
Graph 5.1 Design Curve for Singly Reinforced section in Flexure for Fy=250 N/sqmm and Fc=60 N/sqmm



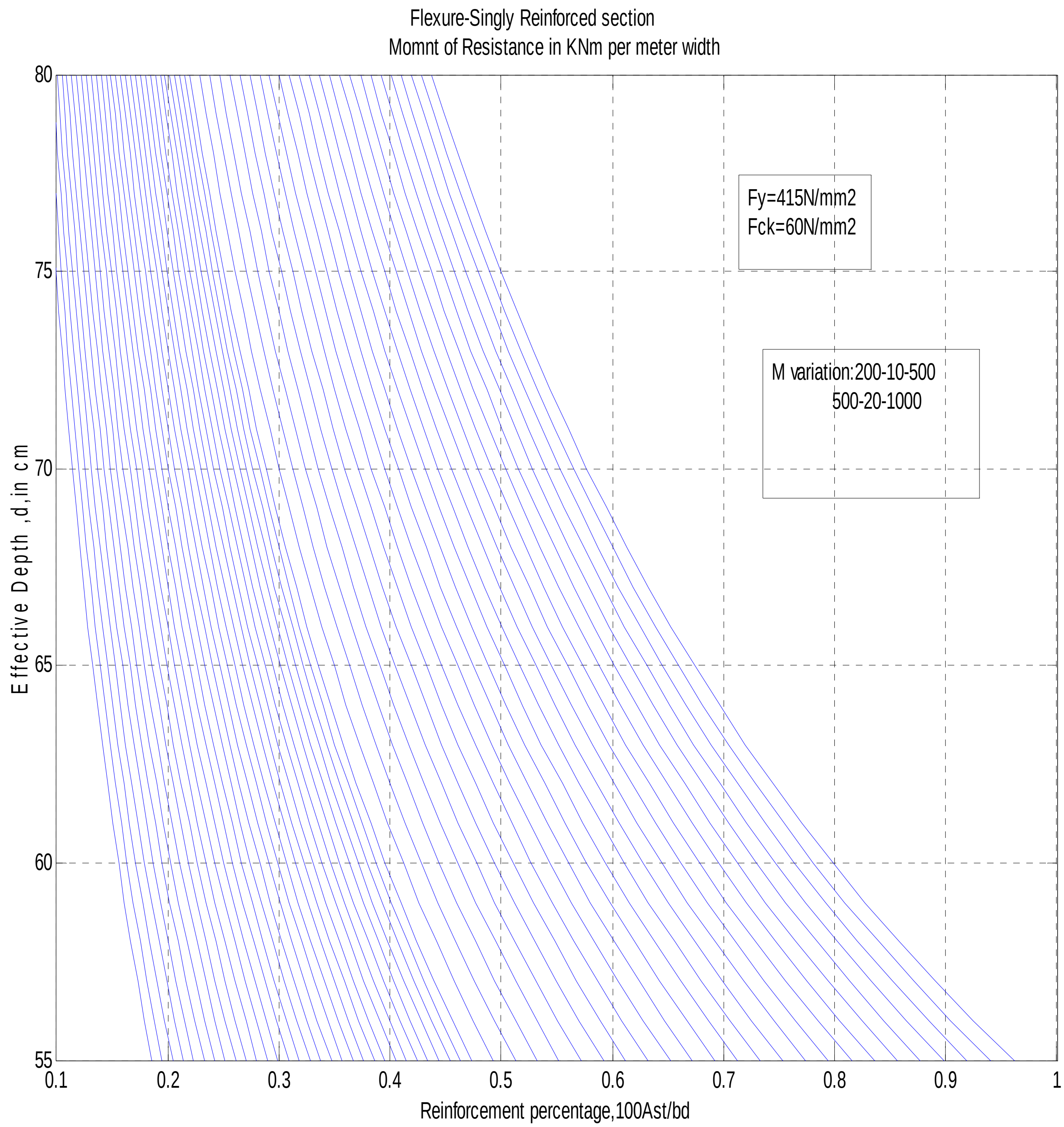
Graph 5.1 Design Curve for Singly Reinforced section in Flexure for Fy=250 N/sqmm and Fc=60 N/sqmm



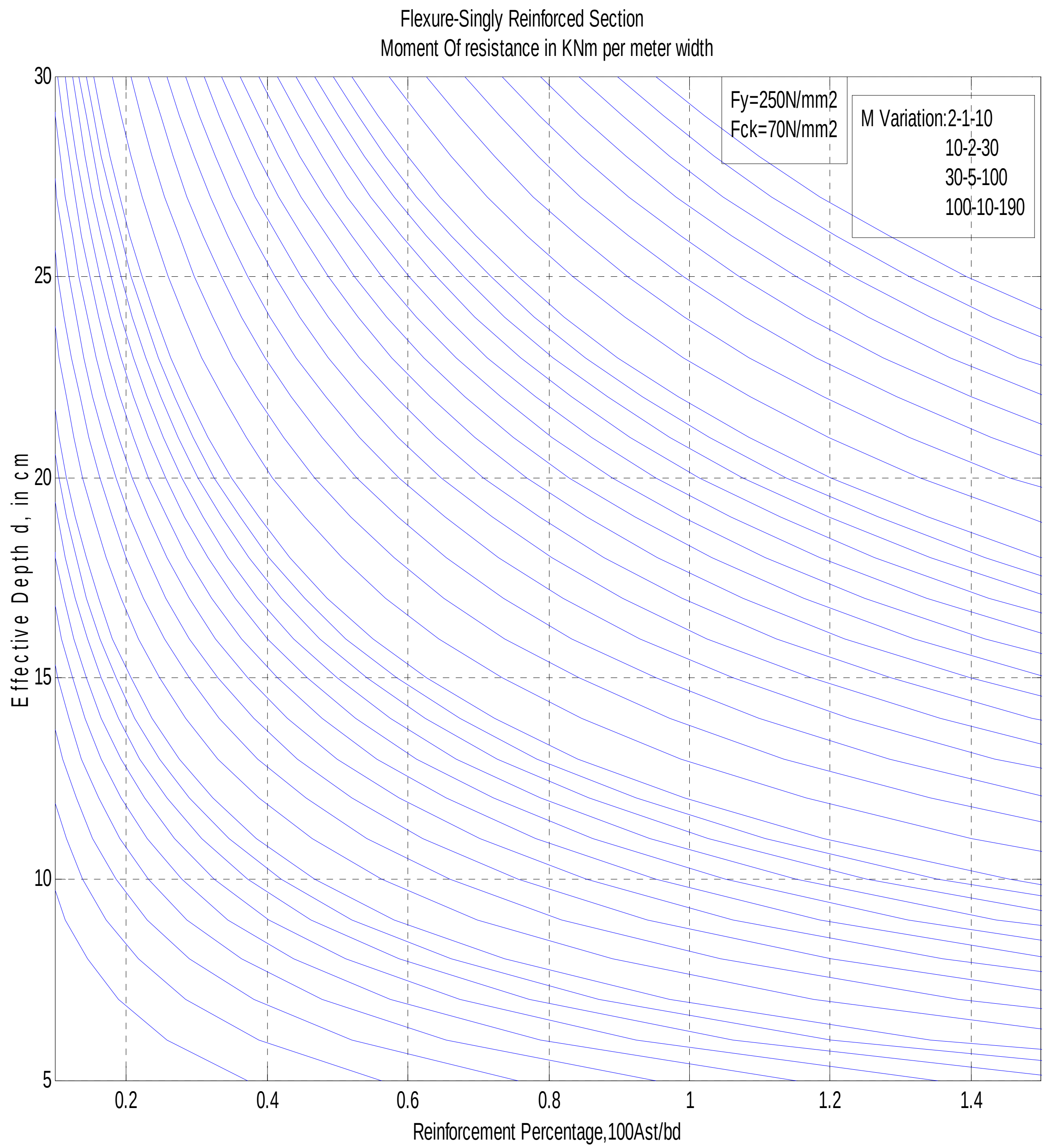
Graph 5.2 Design Curve for Singly Reinforced section in Flexure for Fy=415 N/sqmm and Fc=60 N/sqmm



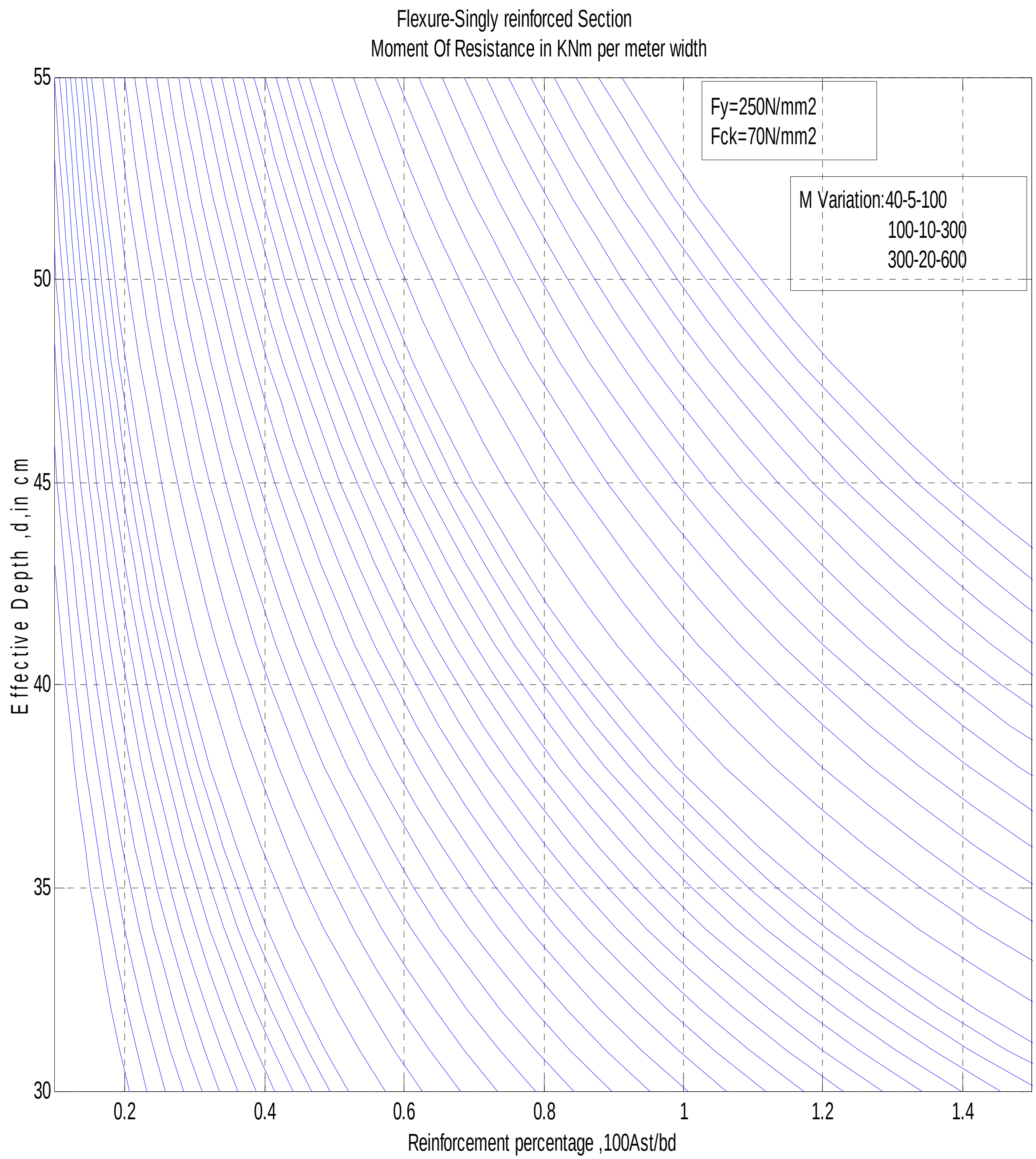
Graph 5.2 Design Curve for Singly Reinforced section in Flexure for Fy=415 N/sqmm and Fc=60 N/sqmm



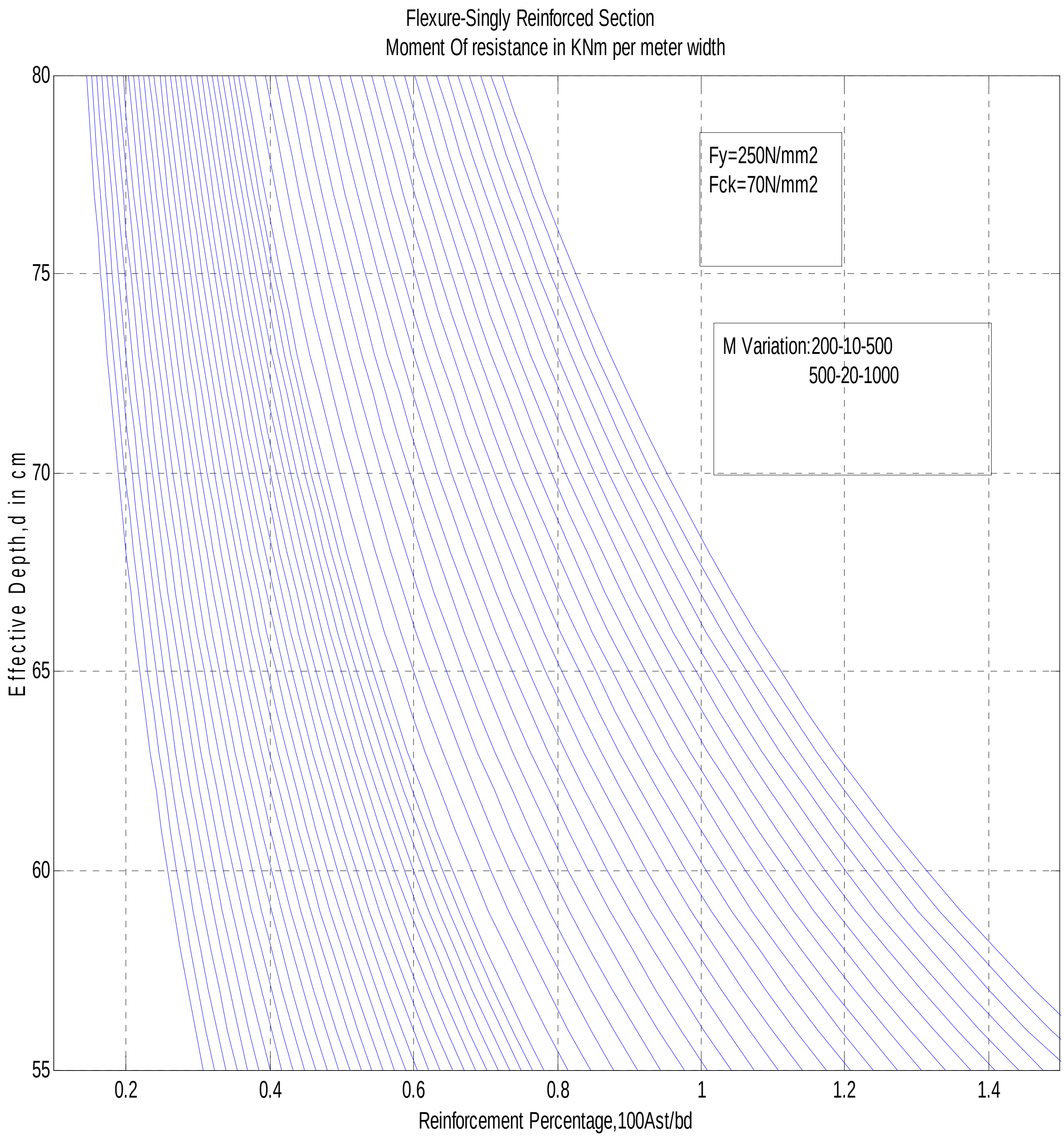
Graph 5.2 Design Curve for Singly Reinforced section in Flexure for Fy=415 N/sqmm and Fc=60 N/sqmm



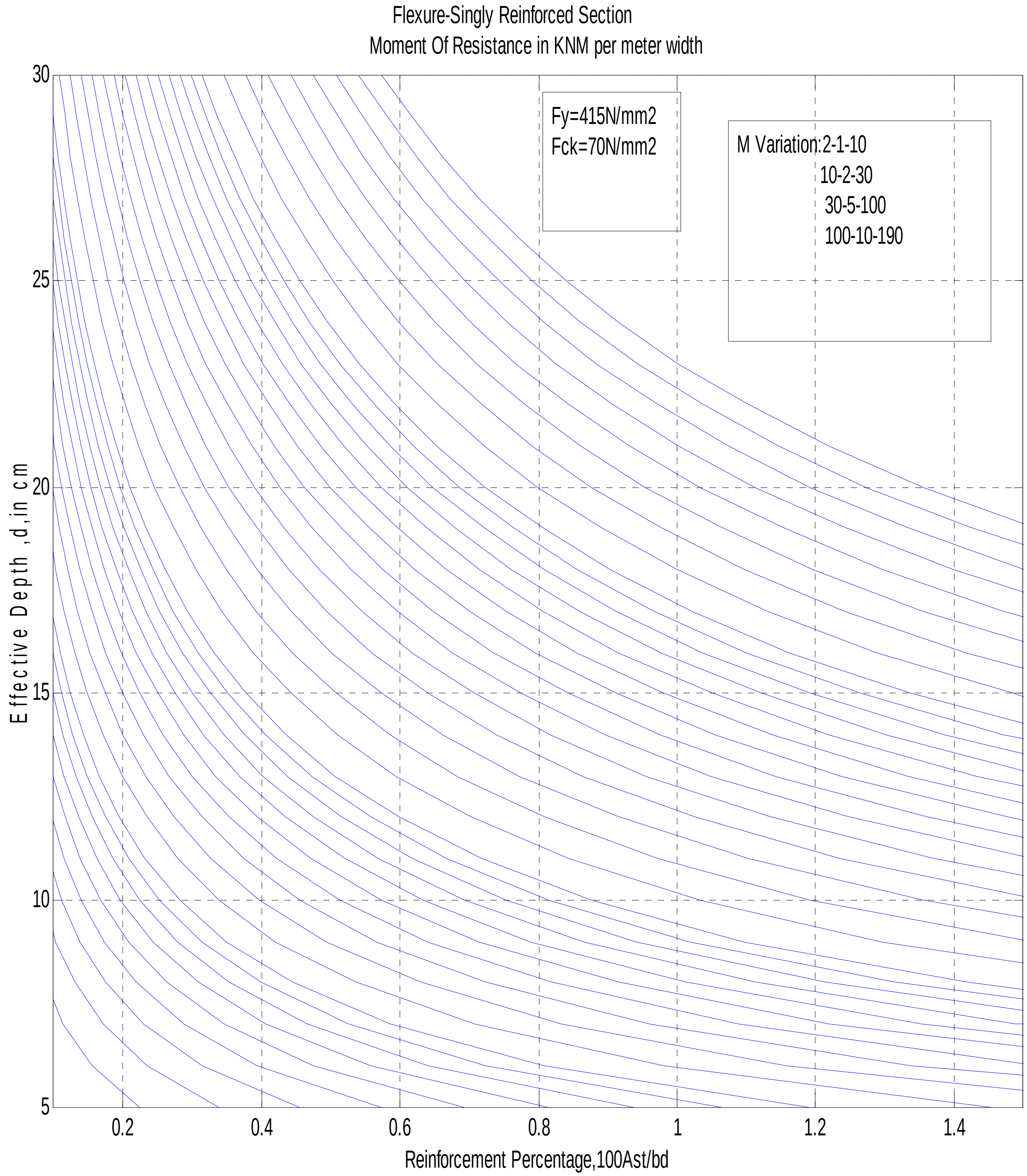
Graph 5.3 Design Curve for Singly Reinforced section in Flexure for Fy=250 N/sqmm and Fc=70N/sqmm



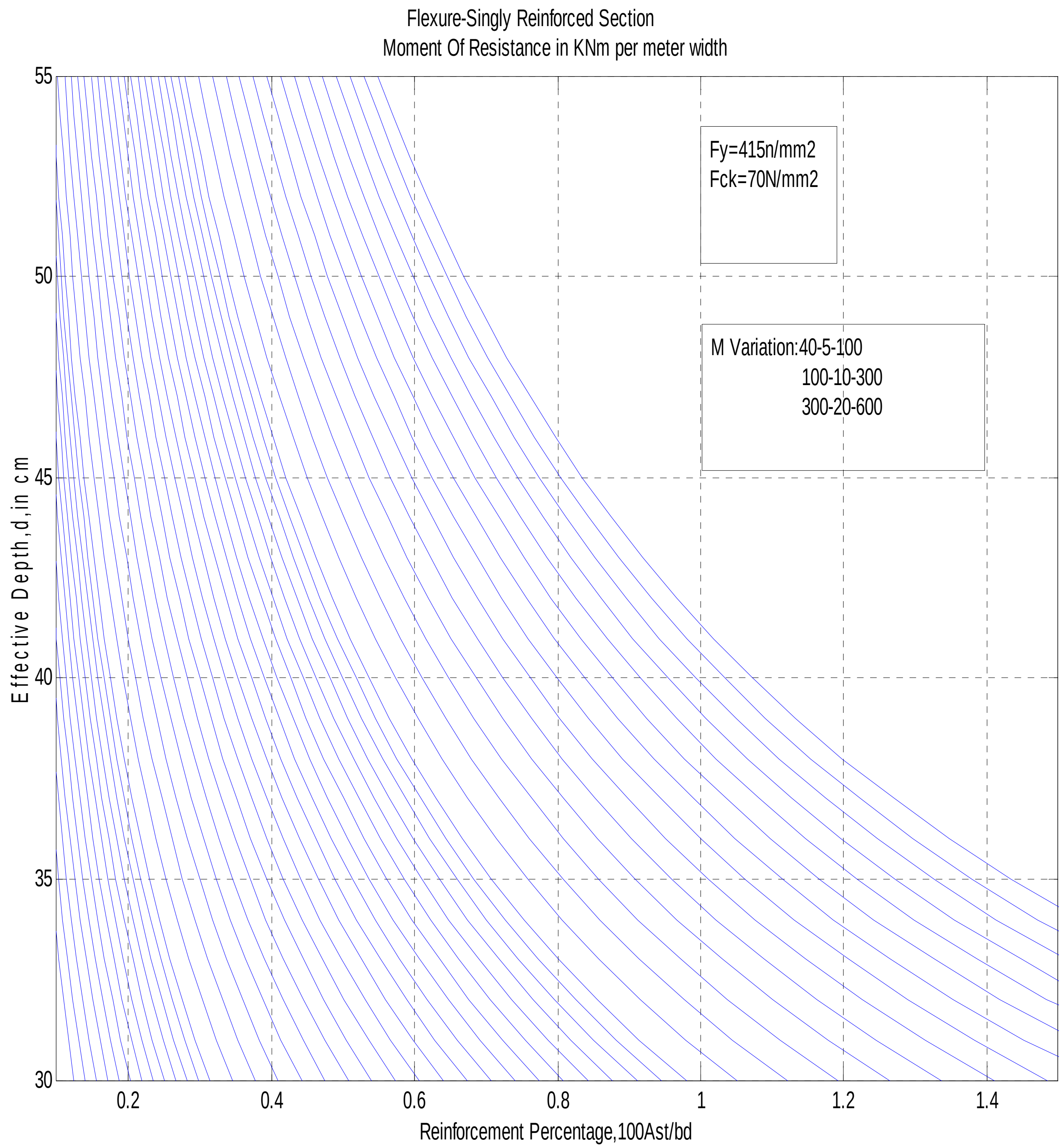
Graph 5.3 Design Curve for Singly Reinforced section in Flexure for Fy=250 N/sqmm and Fc=70 N/sqmm



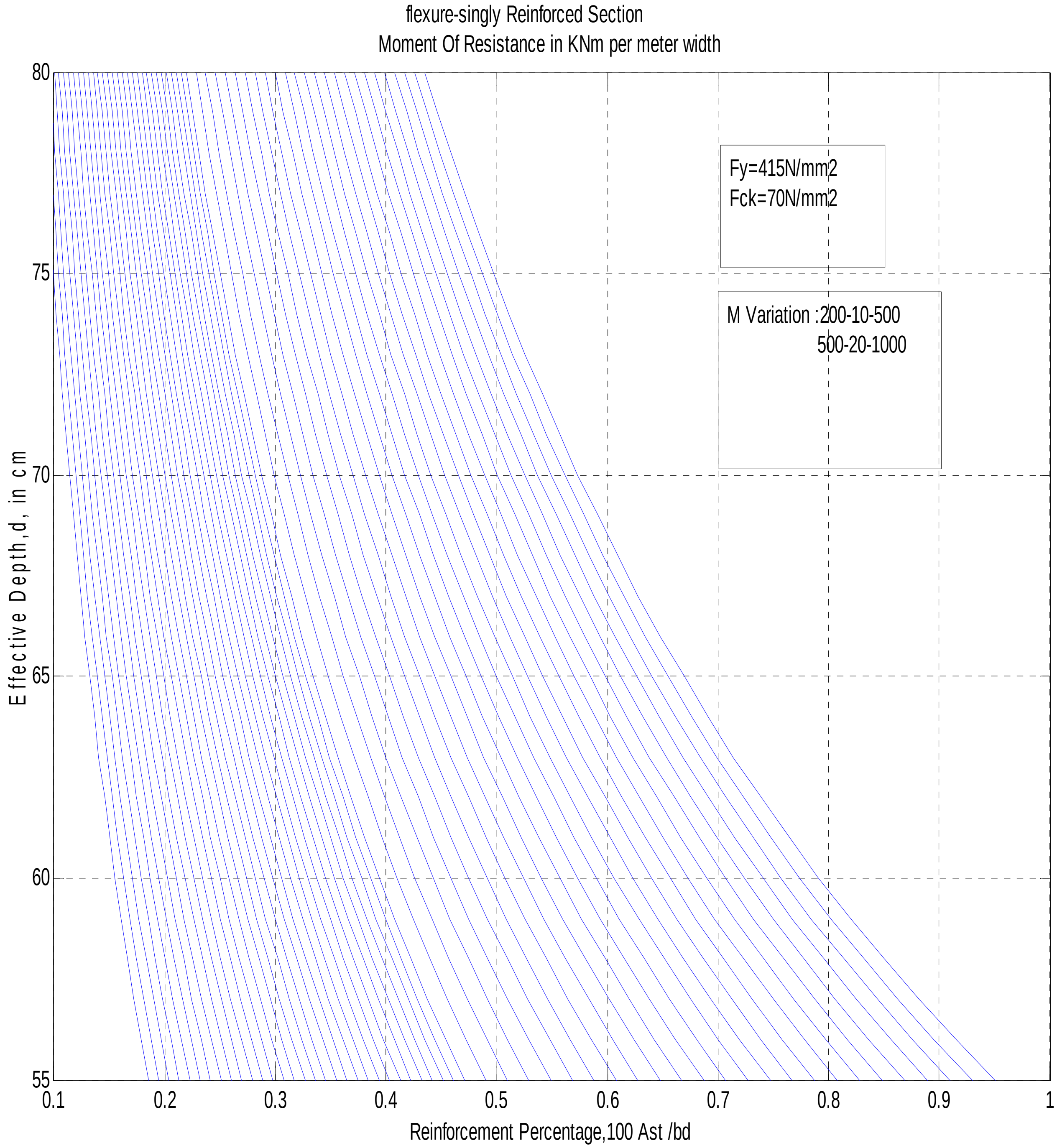
Graph 5.3 Design Curve for Singly Reinforced section in Flexure for Fy=250 N/sqmm and Fc=70 N/sqmm



Graph 5.4 Design Curve for Singly Reinforced section in Flexure for Fy=415 N/sqmm and Fc=70 N/sqmm



Graph 5.4 Design Curve for Singly Reinforced section in Flexure for Fy=415 N/sqmm and Fc=70 N/sqmm



Graph 5.4 Design Curve for Singly Reinforced section in Flexure for Fy=415 N/sqmm and Fc=70 N/sqmm

CHAPTER 6

EPILOGUE

CHAPTER 6: EPILOGUE

6.1 CONCLUSION :

High Performance Concrete with higher compressive strength provides the most economical way for designing the load bearing members and to carry a vertical load to the building foundation through columns by a reduction in the quantity of steel required and also concrete which contribute mainly to the cost of the structural member. The mix design variables affecting the concrete strength which are the most critical in the strength development of concrete including water-cementitious material ratio, total cementitious material, cement-admixture ratio amount of super plasticizer dose are to be analyzed and optimum values of the critical mix design variables are to be taken for obtaining the mix design for the required High Performance Concrete

6.2 RECOMMENDATIONS:

The use of High Performance high strength concrete offers numerous advantages in the sustainable and economical design of structures and gives a direct savings in the concrete volume saved ,savings in real estate costs in congested areas, reduction in form-work area and. The use of High Performance Concrete with its greater durability is likely to result in less maintenance and longer life and with the introduction of life-cycle costing, the long-term economic benefits are likely to more than offset the premium costs for initial construction. To affect this change from Conventional concrete to High Performance Concrete we will have to revive the designing of structures by encouraging use of High Performance Concrete .

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