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Contents

Fraternity News

WELCOME NEW MEMBERS

(Oct - Nov - Dec)

LIFE MEMBERS

M-918 Kumar Rajesh	M-919 Bhor Sunil Dattu
M-920 Nair Biju Krishnan	M-921 Chezayezumal Sachin Kumaran
M-922 Zope Purushottam Eknath	M-923 Patel Chhabil Premjibhai
M-924 Kamat Ganesh Nagappa	M-925 Barapte Harish Baburao
M-926 Patel Jawwad Andul Aziz	M-927 Palwe Ajay Shivaji
M-928 Raje Jagdish S.	M-929 Desai Amruta D.
M-930 Newalkar Suvarna Makarand	M-931 Newalkar Shridhar Gopal
M-932 Patel Yeshvant Ramanbhai	

REVISED STRENGTH AS ON 31-12-2008

Members : 932 Organisation Members : 14 Junior Members : 9

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TOTAL STRENGTH : 992

OUR INTENTIONS

1. To restore the desired status to the Structural Engineer in construction industry and to create awareness about the profession.
2. To define Boundaries of Responsibilities of Structural Engineer, commensurate with remuneration.
3. To get easy registration with Governments, Corporations and similar organisations all over India, for our members.
4. To reformulate Certification policies adopted by various authorities, to remove anomalies.
5. To convince all Govt. & Semi Govt. bodies for directly engaging Structural Engineer for his services.
6. To disseminate information in various fields of Structural Engineering, to all members.

FIELDS CONSIDERED AS ASPECTS OF STRUCTURAL ENGINEERING

- Structural Designing & Detailing
- Computer Software
- Materials Technology, Ferrocement
- Teaching, Research & Development
- Rehabilitation of Structures
- Construction Technology & Management
- Geo-Tech & Foundation Engineering
- Environmental Engineering
- Non Destructive Testing
- Bridge Engineering

& Other related branches

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• Workshop on ISO-9001 for Construction Industry	150
• Brain Storming Session on Use of Speciality Products in Structures	200
• Workshop on Software Tools for Structural Design of Buildings with CD	500
• Workshop on Structural Audit	150
• Workshop on-Seismic Design of Building	150
• Workshop on Effective Use of Structural Software.	150
• Workshop on Effective Use of Structural Software - CD	100
• Workshop on Shear Walls in Highrise Buildings	150
• Seminar on Innovative Repair Materials / Chemicals	200
• Seminar on Foundations for Highrise Buildings	150
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- Your viewpoint on current professional practices

While submitting your article for publication, please follow the guidelines given below:

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- Max length of article: 5 pages including tables and figures
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- The matter should be relevant to the subject and should be organized in a logical flow. It may be divided into sections and sub-sections, if necessary.
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- Notations, if used, should be clearly defined.
- Article should be sent by email to isse@vsnl.net with a copy to mail@technoesis.co.in

Articles may be reviewed and suitably edited before publication.

CONSTRUCTION OF TUNNEL BY HARD ROCK TUNNEL BORING MACHINE

Cover Story

Ashok Mujumdar

Introduction:

Municipal Corporation of Greater Mumbai (MCGM) has taken up the project of augmenting water supply to Mumbai using underground tunnels. One such tunnel project is in progress between Veravali, Andheri (E), Mumbai and Yari Road, Andheri (W), Mumbai. In this project, boring through rock is done using a Tunnel Boring Machine (TBM). Today TBMs are found to replace conventional methods of tunneling due to many advantages, which they offer.

In the conventional method, the alignment of tunnel is fixed by triangulation. Once the alignment is fixed, tunneling starts from one end and proceeds to the other end. If the length of tunnel is more, shafts are driven at convenient distances, and are progressed from both the sides or an approach tunnel is driven till main tunnel to facilitate working. The work starts from both the ends until they meet. Before starting the work the profile of tunnel is marked on the face of rock. The drilling pattern and number of holes to be drilled is decided. With the jack hammers the holes are drilled according to the pattern. Once the pattern is drilled, the holes are filled with gelatin sticks and timer detonators. Once the electric supply is given, the detonators explode igniting the gelatin sticks, which lead to cracking of the rock. After all the bad gases are defumed, the process of removing all loose rock pieces starts. The cut rock material is then transported using trolleys or heavy dumpers depending upon the size of tunnel. This process continues until the work is over.

With the modern technology and heavy engineering, the conventional method of tunneling is replaced by tunnel boring machines (TBM), which can bore through even hard rocks. This method is not only much faster than the conventional method but is also less cumbersome and results in smoother tunnel section. However in this process also before starting the work one has to drive a tunnel of required length to make room for assembly of TBM. At the starting end a large shaft is driven vertically to go down to the required level where the horizontal tunnel starts. The length of TBM used in the present case is around 70 meter and this length of tunnel is driven with conventional method. The machine parts are carried down through this shaft and assembled below. TBM is then mounted on rails specially designed for this purpose. The alignment of tunnel is fixed and subsequently maintained by laser rays. The operations of TBM are computerized.

The boring with TBM is done with the help of cutter blades the number of which depends upon the diameter of tunnel to be bored. The blades rotate in different directions. In the present case the starting tunnel diameter is 3.4 m, which is finished to 3.0 m after lining. The rock is cut into small fragments (3” to 4”), which are taken out from the conveyor belt provided in the machine. The trolleys are placed on the rail behind the TBM and are transported through the shaft up by hoists. The advantage of TBM is that it yields a fairly accurate and round shape of bore in a less cumbersome manner than the conventional method.

Salient Features of the Project:

General:

Name	:	Construction of underground tunnel from Veravali, Andheri (E), Mumbai to Yari Road, Andheri (W), Mumbai – shafts and allied works.
Owner	:	Municipal Corporation of Greater Mumbai
Contractor	:	Patel Engineering Ltd.
Total Cost	:	Rs. 138 Crore

Technical Details:

Dia of Bored Tunnel	:	3000 mm
Diameter of Steel Liner	:	2225 mm
Finished dia with steel liner	:	2200 mm
Length of Tunnel	:	6100 m (Total length)
Veravali to Adarshnagar	:	4300 m
Adarshnagar to Yari Road	:	1800 m

Diameters of Wells:		
At Veravali	:	6.0 m
At Adarshnagar	:	8.0 m
At Yari Road	:	11.50 m
Length of Shafts:		
At Veravali	:	86 m
At Adarshnagar	:	46 m
At Yari Road	:	50 m
Laying of Surface Pipe Line	:	3700 m

Details of Tunnel Boring Machine:

Type	:	Hard Rock Tunnel (can bore through rock strength up to 250 MPa)
Manufacturer	:	Herrenknecht, Germany
Excavation dia	:	3.0 m
No. of Cutters	:	22
Total length including backup	:	70.0 m
Electric power required	:	800 KW
Alignment Guidance System	:	By Laser
Mode of Operation	:	Fully computerized
Muck transportation	:	

Inside tunnel … by muck wagons and loco on rails

Lifting from shaft … by 20 T capacity EOT Crane

Current Status of Project:

The Contractor has already completed boring of 1st drive of 4368 m in 14 months, which is one month ahead of schedule. Boring for 2nd drive is now in progress. M.S. liner work and concreting behind liner for 1st drive will be started shortly. Project is expected to be complete by December 2010.

Author:

Mr. Ashok Mujumdar is a civil engineer with special interest in the field of structural rehabilitation. He can be reached at ashokmujumdar63@gmail.com.

Finished Tunnel Cross Section with Defuming Pipe

Working Platform for TBM

REVIEW OF SOME CLAUSES AND PROVISIONS OF IS 456:2000

Dr. B.N. Pandya

Abstract:

The present study deals with the modifications of various clauses of IS 456:2000 for effective utilization of these provisions in practice. A review of all modified clauses and provisions of IS 456:2000 have been carried out and each and every clause of previous IS 456 is compared with present provisions of IS 456 and comments are given. Simultaneously, modified clauses are compared with similar provisions of international codes such as ACI 318:02, BS 8110:1997(Part 1 & Part 2) and AS3600:01, so as to study the effectiveness of these clauses in practice. The comparative study as done in present work indicates that there is a scope for improvement in the current provisions of IS 456:2000.

Major observations:

On parametric comparative study carried out in present work, several observations on materials and design aspects of RC structures are made. However only important ones are presented here in below:

IS 456:2000, has made major changes in use of material, specifically on different grades of concrete, types of cements, mineral and chemical admixtures. Elaborate provisions on durability and acceptance criteria have been outlined.

Revised IS 456 permits use of ten common type of cements as available to suit present needs and requirements of constructional conditions, and varieties of mineral admixtures, which not only improve long-term durability but also enhance ecological profile of concrete. This gives an opportunity to customize cements and admixtures for particular requirements.

Introduction of five exposure conditions is one of the most significant revision that influences detailing of reinforcement and member sizes.

Revised code permits higher grades of concrete, to include high strength concrete even up to 80MPa. This is a progressive and revolutionary provision in line with the present practices in developed countries. Thus incorporation of higher grades in IS 456:2000 is a welcome step and definitely spurs the use of high performance concrete on a large scale in India.

In present code, minimum grades of concrete for RCC as well as for PCC are defined according to degrees of exposure conditions. Accordingly, minimum grade of concrete specified in revised code is M20, which is higher than previously specified grade of M15.

Short-term modulus of elasticity Ec has been reduced to by around 12% on the same line as in AS3600. Thus the code moves towards the realistic value of Ec keeping in view use of all advanced available materials, higher grades of concrete, types of minerals/ chemical admixtures and stiffness of the structure.

Aspect of concrete durability has now gained utmost importance in the revised code. Accordingly clauses on durability requirements are upgraded and elaborated under main body of code. The revision incorporated in IS 456:2000 will bring in better and durable concrete structures. Durability considerations of minimum grade of concrete and cover requirements will influence design and detailing. Thicknesses and sizes of members under severe to extreme exposure conditions will increase because of minimum cover requirements. Similarly limitation on maximum water cement ratio will necessitate use of water reducing agents.

Minimum cover requirements incorporated in IS 456:2000 from the point of view of durability and fire rating requirements have been linked with grades of concretes instead of giving a blanket minimum cover.

Revised code stipulates minimum cement content and water cement ratio for various grades of concrete according to exposure conditions. The minimum cement content for mild and extreme environment has been increased. For the first time maximum cement content has been introduced primarily to minimize damage to concrete members due to increased heat of hydration. Thus, apart from heat of hydration, specification of maximum cement content also encourages the use of various mineral admixtures such as flyash, GGBS, silica fume, metakoaline and rice-husk in concrete.

The present edition introduces maximum limit on Cl_2 content in fresh concrete in terms of maximum total acid soluble Cl_2, which is expressed in kg/m^3 of concrete. But present limits are much below the threshold values for initiation of corrosion.

The clause on concrete mix proportioning has been thoroughly revamped, to emphasize use of design mix concrete based on performance requirement and not on prescriptive requirement. Standard deviation requirements for design mix concrete have been streamlined to eliminate over conservative design as per earlier edition and as given in IS 10262.

The quality control on concrete with introduction of empirical conditions of acceptability will influence construction practices at sites.

Norms for curing concrete made with blended cements or replacing cement with mineral admixtures, have been made more stringent, which further improves durability of concrete.

Provisions for structural design by WSM have been put in Annexure B of the present code giving greater emphasis on LSM design. The shifting of WSM to Annexure B will encourage use of LSM design, as per international trend.

The clause on fire resistance has been enlarged. Present codal provision provides some basic information with regard to various parameters influencing fire resistance rating of reinforced concrete structures in order to aid the designer to consider fire hazards and certain protection features which could be kept in perspective while doing structural design and detailing.

The code has modified the bending moment coefficient from 1/24 to 1/16 so as to take into account the advantage of moment redistribution, flexural failure behaviour of structure at midspan, and available reserve load carrying capacity of structures at midspan.

Some changes have been made in the design provisions of Section 3, 4 and 5 but these are not very significant. It is observed that most of the provisions related to design aspects remain untouched. Some of the new provisions that are added (e.g. those related to design of wall and corbels) seem to be inconsistent with the basic understanding of structural behaviour

The present code has incorporated the formula for the stability index 'Q' which was missing in the previous edition of IS 456. This is a right step, as it requires determination of sway and non-sway conditions of columns.

A clause on design and detailing of corbels has been introduced with design provisions for corbels based on strut and tie method. Further a detailed chapter on analysis and design of wall is introduced. In addition to these, procedures for estimation of enhanced shear strength close to support in limit state method as well as in working stress method and flexural crack widths have been introduced in revised code to meet present need for design of such structures.

Recommended further studies:

Following possible areas of future studies in respect of IS 456:2000 are recommended:

The present study has focused only on comparative studies of modified clauses of present edition of IS 456 with old ones. These do not limit the scope to verify suitability and effectiveness of each clause for optimum use of IS 456:2000. This would enhance the potential for practical application and help in preparing explanatory handbook on IS 456:2000.

The present work focused only on comparative studies of various design methods proposed for corbel design. Therefore influence of various parameters such as *av, a/d* ratio*,* grades of concrete, strength of steel *fy,* Ast1 (area of main steel), Ast2 (area of horizontal steel) and x (depth of stress block) on the functioning of corbels can also be studied.

The chapter on wall in present edition is similar to that in Australian code. It appears suitable research and investigation work has not been made in India. Therefore present work focuses only on the comparative study of clauses related with axial load design of wall with some of that in the international codes. These studies can be further extended by conducting experiments on walls so as to investigate actual failure mechanisms of wall and formulate analysis of axial strength of wall with respect to slenderness, boundary conditions and general wall behaviour. There is an urgent need for investigation of RC walls in two-way action (i.e. supported on all four sides) for buckling and under the axial compression.

Author:

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Missing You

In the past few months, ISSE journals and other correspondence sent to some of our members have been coming back undelivered. It appears that they have moved to a new address. A list of such members is given below. We are very keen in having their latest contact details with us so that we can reach them in future.

If you know any of these members, please ask them to get in touch with us (Phones: 022-24365240, 24221015) or send an email to isse@vsnl.net or update their contact details through our website www.isse.org.in.

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ARBITRATION FOR RESOLUTION OF DISPUTES

N. N. Shrikhande

INTRODUCTION:

Construction industry happens to be one of the most dominant industries the world over and in a developing country like ours; the horizons for this industry have no limit. In this scenario and with magnitudes and complexities of engineering projects constantly growing, there is a natural growing consciousness among the involved agencies about their rights & responsibilities, which are fixed by a "contract" between the agencies which is defined as "an Agreement enforceable by law".

While ideally every party to any contract essentially desires that work in hand is executed in an atmosphere of mutual confidence and harmony without wishing to extract undue advantage at the cost of other, this does not necessarily so happen in practice due to possibilities existing in mistaking / misunderstanding the intentions and interpreting events / actions differently. This gives rise to disputes (which imply an assertion of right by one party and a repudiation thereof by the other party) and differences (which are not necessarily disputes but become disputes when not resolved mutually) which need to be resolved by an appropriate dispute resolution mechanism. Arbitration is one such mechanism which is the subject matter of this paper. While the disputes may be between an employer (client) & a contractor, an employer (client) and a consultant (the term is used to denote Architect, Structural Consultant, Service Consultant/s, Project Management Consultant etc as the case may be), a contractor & a sub-contractor etc., this paper essentially deals with disputes between an employer & a contractor.

BREACH OF CONTRACT, DISPUTES:

A contract imposes certain obligations on both the employer and the contractor for the execution of a project. In case, the employer does not have his own in-house facilities for performing certain obligations (such as planning, designing, supervising the works etc.), he may enter into a separate contract with a consultant. However, with no contract between the consultant and the contractor, the obligations of the consultant become a part of the employer's obligations in so far as the contract between the employer & the contractor is concerned.

Non-performance of any obligation by any party at any stage of the contract constitutes breach of express terms of agreement by the said party and hence a breach of contract attributable to that party. But when a breach cannot be attributed to any party, it is no breach at all.

Breaches are total in case of failure to perform obligation in whole, such as the employer cancelling the contract before the work begins or the contractor refusing to perform on award of work. Breaches are partial in case of failure of a party to perform obligation in parts resulting in loss and / or delay in completion.

Every breach of contract leads to a dispute and gives the other party an immediate cause of action, a right to obtain a remedy and a right to damages as compensation for any loss flowing from the breach. However, at the same time the breach does not relieve the injured party from liability to perform his part of contract except where breach goes to the root of the contract.

The details in regard to non-performance of the obligations by the parties leading to disputes are indicated below-

A] **Attributable to the Employer**

I) **Deficiencies in Tender documents:**

- Inaccurate information, insufficient investigations / surveys in regard to items like contours, type of strata, sub-soil water level, access to site, availability of water / power etc
- Ambiguities in conditions (eg. loosely worded stipulations, conflicting statements etc.)
  - Unworkable stipulations (items like time of completion etc.)
  - Inadequate stipulations, (e.g. basic prices not mentioned where necessary, no clarity about escalation etc.)
  - Badly drawn / sketchy drawings, defective design concepts etc
  - Carelessly prepared specifications / BOQ leading to quantity variations, subsequent revisions etc

ii) **Delays:**

- In appointing Consultants, if any
- In giving timely possession of site and promised facilities
- In approvals, permissions (NOC, CC, etc.)
- In supplying drawings and details well in advance
- In providing clarifications on drawings / in giving timely instructions/ decisions on revisions
- In supplying materials & equipments in time (where it is the responsibility of the Employer)
- In the work by other agencies appointed by the Employer
- In appointing nominated specialist agencies / suppliers etc

- In making timely payments
- In procuring final completion and allied certificates from statutory authorities (Corporations, Airport Authorities, Fire Fighting etc)
- In taking over

iii) **Other Factors:**
- Revisions in scope of work
- Rescheduling of work, acceleration of part/ whole work
- Unreasonable rejection of acceptable work
- Unreasonable recoveries including Liquidated Damages
- Suspension / stoppage of work
- Non payment of interest etc. (if included in the Contract)
- Bad handling / usage during defects liability period
- Wrongful / illegal termination of Contract

B] **Attributable to the Contractor**

i) Desperate quoting due to competition or lack of experience or purposeful action

ii) Defective, sub-standard work due to deficiencies in materials and workmanship

iii) Defective design (in respect of his own design)

iv) Deficiencies in site management resulting in delays in completion:
- Inadequate mobilisation
- Failure to appoint qualified / experienced engineers, adequate / competent labour and supervision
- Deficient planning (Physical & Financial), failure to submit planned programme
- Negligence in regard to control over materials, safety measures etc
- Failure in maintaining / submitting labour reports (non-adherence to labour laws regarding wages, holidays, insurance etc.)
- Unauthorised sub-letting
- Misappropriation of materials supplied by the employer
- Causing damage to property / other works

v) Abandoning Contract / failure to complete the Contract

C] **Attributable to None:**
- Changes in site conditions
- Changes in Codes
- Changes in Laws
- Unforeseen market fluctuations
- 'Excepted Risks'

DISPUTE RESOLUTION:

Arbitration, an informal Process:

Once disputes / differences arise, the aggrieved party would like to get a satisfactory settlement of its claims through a proper forum. Litigation in courts is often considered as the last step since it strictly involves statutory procedures adopting Acts like The Indian Contract Act 1872, The Limitation Act, The Evidence Act, Code of Civil Procedure etc and is normally a time- consuming process. Arbitration, on the other hand, is considered as a more informal, convenient and speedier process wherein an independent third party as Arbitrator/s can help to solve the problem in a dispassionate manner.

Arbitration Agreement:

For the parties to refer the matter to arbitration, it is necessary to have an arbitration agreement whether in the form of an appropriate clause in the contract or a separate agreement suitably made later.

Arbitrator:

i) There are no qualifications as such as prescribed for an Arbitrator. But normally independent and impartial professionals- knowledgeable and experienced - are preferred. They may be Engineers/ Architects, Retired Judges / Advocates etc.

ii) Certain code of ethics is implied for an arbitrator. It is understood that the arbitrator
- should not himself seek or advertise for his appointment
- should not consider himself as an advocate of the party appointing him
- should disclose any interest or relationship likely to affect impartiality
- should not misconduct himself (eg. refuse to record all evidence, decide a dispute on personal knowledge or act in a manner which causes miscarriage of justice etc.)

iii) On appointment, it is desirable for the arbitrator to check that his appointment is in order and to carefully ascertain the extent of his authority.

Applicable Law:

The law applicable would be The Arbitration and Conciliation Act 1996 (A & C Act 1996) which is based on the Model Law and Rules adopted by The United Nations Commission on International Trade Law (UNCINTRAL). In its different Parts, this Act covers topics like the Composition of the Arbitral Tribunal (AT), Conduct of Arbitral Proceedings, Arbitral

Award and Recourse against the Awards etc. A brief summary of the details is indicated here below -

i) **Appointment:**

a) The appointment of Arbitrator/s shall be as per the provisions of the contract.

b) There can be a sole arbitrator if accepted by both the parties. Otherwise one arbitrator is nominated by each party and the third arbitrator (Presiding Arbitrator) is nominated by the two arbitrators. If there is a difference between the arbitrators, the Chief Justice of the Hon'ble High Court decides.

ii) **Normal working procedure:**

A normal working procedures involves-

- A preliminary meeting to decide on further schedule, fees to the Arbitrator/s etc.
- Submission of documents such as –
  - Statement of Claims (SOC)
  - Statement of Defence (SOD) i.e. Reply to SOC and Statement of Counter Claims (SOCC), if any
  - Rejoinder to SOD and Reply to SOCC
  - Rejoinder to SOCC
- Inspection of documents,
- Further meetings involving oral/ written submissions by the parties, examination/ cross examination of any witnesses, internal meetings between the members of the AT etc.
- Making the Award

iii) **Award:**

a) The arbitral Award is the final decision of the arbitrator/ AT and is considered as the decree of the court. It has to be in writing and it should state the reasons upon which it is based (unless agreed otherwise by the parties). In case of AT, the majority decision governs. After the Award is given, any computational errors can only be corrected. Similarly if so agreed by both the parties, a party can request for interpretation of a specific point or part.

b) The AT may at any time during the arbitral proceedings make an interim award on any matter with respect to which it may make a final award.

c) An arbitral award can be set aside only by a Court, if

- it is proved that a party was under some incapacity
- the arbitration agreement was not valid under law
- enough opportunity was not given to a party
- matters covered were beyond the scope of submission to arbitration

DAMAGES FOR BREACH OF CONTRACT:

As stated earlier, every breach of contract entitles the injured party to damage for the loss he has suffered. Measure of damage depends on a wide variety of factors. E.g. In case of total breach by the contractor, the employer can terminate the contract and forfeit the security deposit. The contractor on the other hand, in case of total breach by the employer, is entitled to receive damage for preliminary expenses plus reasonable compensation.

In case of partial breach by the contractor, the employer is entitled to bring an action for damages. He normally relies on the clause of "Liquidated Damages" if the same is provided in the contract. Insofar as the contractor is concerned, in case of partial breach by the employer he claims for:

- On-site overheads – Costs for supervision hutting, plant and equipment etc
- Off-site overheads – (H.O. overheads) and profits-percentage may vary from job to job and from agency to agency
- Inflationary costs – In respect of labour and materials
- Loss of productivity –Very hard to assess the available profitable use of labour and plant elsewhere. Many times an arbitrary percentage is claimed
- Loss of profit – When work is carried out partly and then contract repudiated, the loss would depend on the rates for completed work and rates for balance work. Difficult to assess.

If both parties agree to the rescission of the contract, there can be no suing for non-performance by any party.

CONCLUDING REMARKS:

Before closing, I would make a few observations based on experience as follows-

For engineering contracts, particularly such ones going beyond merely technical matters and involving important legal aspects, arbitrators comprising engineers and legal persons would prove an ideal tribunal.

While the arbitration is intended to be a speedy and economical process, it would appear that in actual practice inordinate and avoidable delays do occur causing inconvenience and unnecessary expenditure.

Although an arbitration award is a decree of the court, there appears to be a growing tendency to challenge the awards in the High Court not necessarily on any sound grounds.

Author:

N.N. Shrikhande is a senior structural consultant and the Chairman of Shrikhande Consultants Pvt. Ltd. He has worked as an arbitrator on several major cases. He can be reached at scplvashi@gmail.com.

DESIGN OF A SIMPLY SUPPORTED ONE-WAY SLAB LOADED BY A STRIP LOAD ALONG THE SPAN

By Umesh Dhargalkar

Synopsis:

IS 456: 2000[1] lays down the method of calculating the design parameters for one-way slabs loaded by concentrated loads. There are, however, no direct recommendations for one-way slabs loaded with a strip load along the span of the slab. Starting with the provisions for concentrated loads, this paper derives a closed form solution for designing a simply supported one-way slab loaded by a strip load along the span.

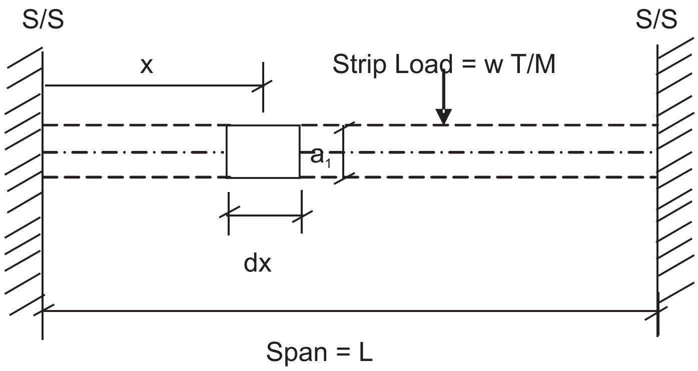
Keywords: *one-way slab, strip load, closed form solution*

Introduction:

IS456: 2000[1], Clause 24.3.2 gives a method for designing a one-way slab loaded by a concentrated load, in which an effective width of slab is calculated and is designed for the bending moment caused by the concentrated load. The code also provides that for two or more concentrated loads placed in a line in the direction of the span, the bending moment per unit width of the slab shall be calculated separately for each load and added together for design calculations. Based on these provisions the present paper evolves a closed form solution for designing simply supported one way slabs loaded by a strip load along the span, which can be readily used in a design office.

Discussions:

Refer to the following figure of a slab loaded by a strip load



Consider an element of the strip load of length dx along the span with its centroid at a distance x from the nearer support edge.

Elemental load $dP = w\,dx$

Elemental bending moment at the location of load

$$dM = dP\,\frac{x\,(L-x)}{L} = \frac{w\,x\,(L-x)}{L}\,dx$$

Using clause 24.3.2.1 in IS456: 2000[1],

$$\text{Effective width } b_{ef} = k\,x\left(1 - \frac{x}{L}\right) + a_1 = \frac{k\,x\,(L-x) + a_1 L}{L}$$

$$\text{B.M. per unit width of slab} = \frac{dM}{b_{ef}} = \frac{w\,x\,(L-x)}{L}\,dx\,\frac{L}{k\,x\,(L-x) + a_1 L} = \frac{w\,x\,(L-x)}{k\,x\,(L-x) + a_1 L}\,dx$$

Integrating for the entire strip,

$$\frac{M}{b_{ef}} = \int_{x=0}^{x=L/2} 2\,\frac{dM}{b_{ef}} = \int_{x=0}^{x=L/2} 2\,w\,\frac{x\,(L-x)}{k\,x\,(L-x) + a_1 L}\,dx$$

$$= 2\,wL\int_0^{L/2} \frac{x\,dx}{k\,x\,(L-x) + a_1 L} - 2\,w\int_0^{L/2} \frac{x^2\,dx}{k\,x\,(L-x) + a_1 L}$$

$$= -2\,wL\int_0^{L/2} \frac{x\,dx}{k\,x^2 - k\,L\,x - a_1 L} + 2\,w\int_0^{L/2} \frac{x^2\,dx}{k\,x^2 - k\,L\,x - a_1 L}$$

Referring to standard formulas of integration[2],

Let $X = a\,x^2 + b\,x + c = k\,x^2 - k\,L\,x - a_1 L$

where $a = k$, $b = -k\,L$ and $c = -a_1 L$

Let $D = b^2 - 4\,a\,c = k^2 L^2 + 4\,a_1 k\,L > 0$

$$\frac{M}{b_{ef}} = -2\,wL\int_0^{L/2} \frac{x\,dx}{X} + 2\,w\int_0^{L/2} \frac{x^2\,dx}{X}$$

$$= -2\,wL\int_0^{L/2} \frac{x\,dx}{X} + 2w\left\{\left[\frac{x}{a}\right]_0^{L/2} - \frac{c}{a}\int_0^{L/2} \frac{dx}{X} - \frac{b}{a}\int_0^{L/2} \frac{xdx}{X}\right\}$$

$$= \frac{wL}{a} - \left(2wL + \frac{2wb}{a}\right)\int_0^{L/2}\frac{x\,dx}{X} - \frac{2wc}{a}\int_0^{L/2}\frac{dx}{X}$$

Substituting back for a, b and c

$$\frac{M}{b_{ef}} = \frac{wL}{k} - \left(2wL - \frac{2wkL}{k}\right)\int_0^{L/2}\frac{x\,dx}{X} + \frac{2wa_1L}{k}\int_0^{L/2}\frac{dx}{X}$$

$$= \frac{wL}{k} + \frac{2wa_1L}{k}\int_0^{L/2}\frac{dx}{X}$$

$$= \frac{wL}{k} + \frac{2wa_1L}{k}\left[\frac{1}{\sqrt{D}}\ln\left|\frac{2ax+b-\sqrt{D}}{2ax+b+\sqrt{D}}\right|\right]_0^{L/2}$$

$$= \frac{wL}{k} + \frac{2wa_1L}{k\sqrt{D}}\left\{\ln\left|\frac{aL+b-\sqrt{D}}{aL+b+\sqrt{D}}\right| - \ln\left|\frac{b-\sqrt{D}}{b+\sqrt{D}}\right|\right\}$$

$$= \frac{wL}{k} + \frac{2wa_1L}{k\sqrt{D}}\left\{\ln\left|\frac{kL-kL-\sqrt{D}}{kL-kL+\sqrt{D}}\right| - \ln\left|\frac{-kL-\sqrt{D}}{-kL+\sqrt{D}}\right|\right\}$$

$$\frac{M}{b_{ef}} = \frac{wL}{k}\left\{1 - \frac{2a_1}{\sqrt{D}}\ln\left|\frac{kL+\sqrt{D}}{kL-\sqrt{D}}\right|\right\} \quad \ldots \text{(I)}$$

where

$$D = kL\,(kL + 4a_1) \quad \ldots \text{(II)}$$

Applications:

The equations (I) and (II) can be used very easily for designing a simply supported one-way slab loaded by a strip load along the span. The design will involve the following three simple steps:

1. Substitute known values of span (L), intensity of load (w), width of contact area (a1) and a selected value of constant 'k' (from table 14 of IS 456: 2000) into equation (II) and calculate 'D'.
2. Substitute L, w, a1, k and the previously calculated D into equation (I) and calculate M/ beff.
3. Design for M/ beff.

The following numerical example will illustrate the practical application of the equations developed.

Suppose the effective span of the one way slab = L = 5 M

The intensity of strip load = w = 2 T/M

Width of contact area of strip load = a_1 = 0.25 M

Value of k (Refer to Table 14 of IS456:2000[1]) = 2.48

Using these parameters in equation (II),

D = 166.16 and D = 12.89

Substituting in equation (I),

$\frac{M}{b_{ef}}$ = 3.415 T-M/M, for which the slab can now be designed.

Conclusions:

1. The final equations can be used very easily in a design office for loads such as a wall load. No trial and errors are needed.
2. When the numerical example mentioned in the applications was solved using a computer, wherein the span was divided into 1000 divisions each of 5 mm length, and the bending moment per unit width was summed up for the entire length of the span as per the provisions of Clause 24.3.2 of IS456:2000[1], the results agreed very well. The computed value was also 3.415 T-M/M.
3. By changing the limits of integration, it is possible to derive solutions for partial strip loads. However, the solutions in such cases may not take a simplified form as for the full span strip load.

References:

1. IS456: 2000 Indian Standard: "Plain and Reinforced Concrete - Code of Practice" (Fourth Revision) July 2000.
2. Rinehart Mathematical Tables, Formulas and Curves Enlarged Edition compiled by Harold D. Larsen, Holt, Rinehart and Winston, 1953

Notations:

L	:	Effective span of one way slab
w	:	Intensity of strip load along the span
a_1	:	Width of contact area of the strip load measured parallel to the supporting edges
k	:	Constant having the values given in Table 14 in IS456: 2000
b_{ef}	:	Effective width of slab
M	:	Bending moment
x	:	Distance of an elemental concentrated load from the nearer support
a,b,c	:	Constants in a quadratic equation

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ANALYSIS OF BUILT UP STEEL LATTICED GIRDER BY VARIOUS METHODS

Hemant Vadalkar & Prasad Samant

Introduction :

Analysis of simple beams and trusses are easily carried out by approximate methods. For complex built-up girders, approximate analysis does not provide the realistic results. Approximate analysis is based on certain assumptions. If these assumptions are not valid, then there can be large variation in results.

Complex built up steel girders are used as piling gantries rolling over long spans. The girders are made up of standard steel sections and plate girder combinations. To support heavy reactions from the wheel, plate girder is necessary as a bottom chord. For large span overhangs, more depth is necessary. This is achieved using a built up truss over the plate girder.

An attempt has been made to calculate stresses at top and bottom of these built up girder using various methods. Results of various methods are tabulated and discussed

Example considered for analysis :

A long span girder with overhang of 22.5m and a tie back span of 24m as indicated in fig. 1.0 is considered for analysis

The loading on the girder is shown in fig 1.0

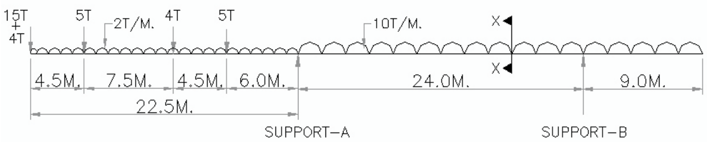

Fig 1.0 GIRDER LOADING DIAGRAM

The girder is not symmetrical about the major axis. The cross section is indicated in Fig 1.1

Elevation of girder is shown in fig. 1.2

From simple statics, shear force and cantilever bending moment at support A, can be worked out as under:

Shear V = = 4+15 + 5 + 4 + 5 + (22.5 X 2)

= 78 T

Moment M = [(4+15)X22.5) + (5X18) + (4X10.5) + (5X6) + (2X22.5X22.5/2)]

= 1095 T-M

The problem under consideration is a three span girder with its cross section shown in Fig 1.1 and loading of problem as in Fig 1.0

Girder Properties **: -**

As shown in Fig 1.1, girder consists mainly of two member Top chord and bottom Chord

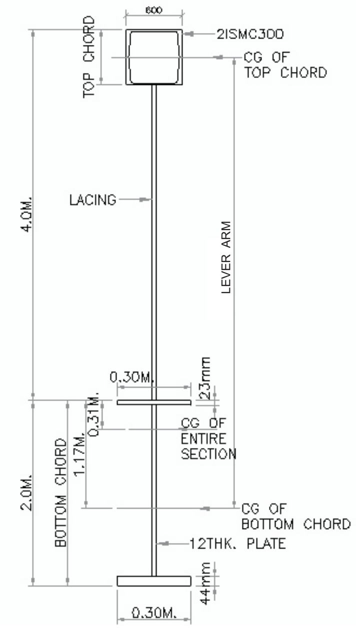

Fig 1.1 X-X CROSS SECTION OF GIRDER

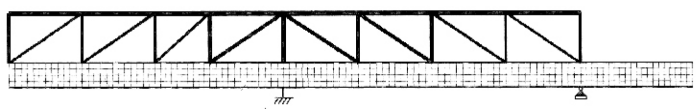

Fig. 1.2 Elevation of Girder

Top chord is made up of 2ISMC 300 .

Properties of top chord

CG of top chord	=	15 cm from top
Area of top chord	=	91.28 cm^2
Iz of top chord	=	12725 cm^4
Z of top chord	=	848 cm^3

Properties of bottom chord

CG of bottom chord	=	117 cm from top (83cm from bottom)
Area of bottom chord	=	440 cm^2
Iz of bottom chord	=	2766229 cm^4
Iy of bottom chord	=	15750 cm^4
Ryy of bottom chord	=	5.98 cm

Ztop of bottom chord	=	23643 cm^3
Zbottom of bottom chord	=	30736 cm^3

For entire girder section of 600cm depth

CG of entire section	=	431 cm from top
Iz of entire section	=	22441500 cm^4
Ztop of entire section	=	52069 cm^3
Zbottom of entire section	=	132790 cm^3
Ztop of bottom chord (entire)	=	723919 cm^3

Analysis: -

Problem is solved using following five methods namely

1. Beam Theory
2. Truss Theory
3. Frame Analysis
4. Strut and Tie Model analysis (STM)
5. Finite Element Analysis (FEM)

1. Beam Theory

The entire girder is considered as a beam with openings in the web. Axial force in the girder is zero and only bending moment is considered for stress calculation. Only areas of top flange and bottom flange are considered to find out the CG of the entire section. Section modulus for top and bottom fibre are used to find out the bending stresses.

Cantilever moment at A is
M = 1095 T-M
Shear force near support A
V = 78 T

Bending stress = (M / I) * y

Using beam theory, stress in top fibre of entire frame
= M / I * y
= (1095 x 100000) / 22441500 * 431
= 2030 Kg/cm^2

Using beam theory stress in top flange of bottom chord
= M / I * y
= (1095 x 100000) / 22441500 * 31
= 151 Kg/cm^2

Using beam theory stress in bottom fibre of entire frame
= M / I * y
= (1095 x 100000) / 22441500 * 169
= 825 Kg/cm^2

Fig 2.0 BENDING MOMENT DIAGRAM OF BEAM ANALYSIS

2. Truss Theory

With a simplified assumption, entire built-up is visualised as a truss having top chord, bottom chord, vertical and diagonal members. In the analysis, stiffness of the individual member against bending is neglected and all connections are assumed as pins.

CG of top chord	=	15 cm from top
CG of bottom chord	=	83 cm from bottom
Lever arm of truss	=	(600 – 15 – 83)
	=	502 cm
Moment at support A	=	1095 T-M

Approximate axial force in top and bottom chord is calculated as given below

Axial Force = Moment / Lever arm
= 1095 / 5.02
= 219 T

Using truss theory, stress in top chord of entire frame
= Force / Atop
= (219 x 1000) / 90
= 2434 Kg/cm^2

Using truss theory stress in bottom chord of entire frame
= Force / Abottom
= (219 x 1000) / 440
= 498 Kg/cm^2

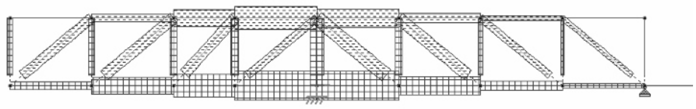

FIG 2.1 AXIAL FORCE DIAGRAM OF TRUSS ANALYSIS

3. Frame Analysis :

For carrying out more realistic analysis, the girder has been analysed as a frame using available software package STAADPro. The frame members are modelled along the centre line with respective properties. Member offsets are used for the plate girder to simulate the connections on top of the girder.

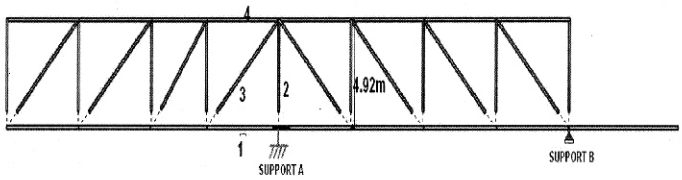

Fig 2.2 LINE DIAGRAM OF FRAME ANALYSIS

From STAADPro analysis

Axial force in Top member 4 = 68 T ;
Moment in Top member 4 = 0.5 T-M
Axial force in bottom member 1 = 85 T ;
Moment in bottom member 1 = 677 T-M
Axial force in inclined member 3 = 22 T

Using frame analysis stress in top chord of entire frame
= (Force / Atop) + (moment/Z)

= (68 x 1000) / 91.28 + ((0.5X100000)/848))
= 745 Kg/cm^2 + 59 Kg/cm^2
= 804 Kg/cm^2

Using frame analysis stress in top flange of plate girder (bottom chord)

= (Force / A) – (Moment/Ztop)

= (85 x 1000) / 440 – ((677X100000)/ 23643))

= 194 Kg/cm^2 – 2864 Kg/cm^2

= -2670 Kg/cm^2

Using frame analysis stress in bottom flange of plate girder (bottom chord)

= (Force / A) + (moment/Zbottom)

= (85 x 1000) / 440 + ((677X100000)/ 30736))

= 194 Kg/cm^2 + 2203 Kg/cm^2

= 2397 Kg/cm^2

Fig 2.3 BENDING MOMENT DIAGRAM OF FRAME ANALYSIS

4. Strut and Tie Model analysis (STM)

The plate girder depth is 2.0m which is substantial compared to the total depth of the girder. For more accurate analysis, the plate girder is simulated using strut and tie model concept. The top and bottom flange is a rectangular plate section and web is simulated as vertical and diagonal members using the width as 1/3rd the length. This approximate model is a reasonably good simulation of the actual structure. The analysis is carried out as a rigid frame and not as a truss as usually done in simple strut and tie models.

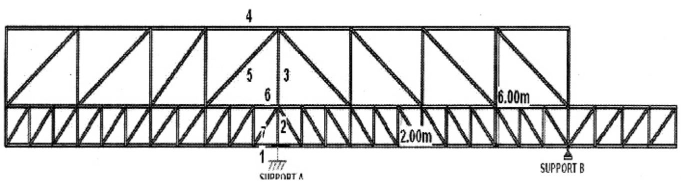

Fig 2.4 LINE DIGRAM FOR STM ANALYSIS

In STM analysis web of bottom chord is model as strut and tie elements where as top & bottom member of bottom chord is model as plate of 300 mm wide and 23mm & 44mm thickness respectively.

From STAAD Frame analysis

a) Axial force in Top member 4 = 107 T ;
Moment in Top member 4 = 3.0 T-M

b) Axial force in bottom member 6 = 54 T ;
Moment in bottom member 6 = 0.7 T-M

c) Axial force in bottom member 1 = 235 T ;
Moment in bottom member 1 = 0.3 T-M

d) Axial force in inclined member 5 = 52 T

e) Axial force in inclined member 7 = 55 T

Using STM analysis stress in top chord of entire frame

= (Force / Atop) + (Moment/Z)
= (107 x 1000) / 91.28 + ((3.0X100000)/848))
= 1173 Kg/cm^2 + 354 Kg/cm^2
= 1527 Kg/cm^2

Using STM analysis stress in Top member of bottom chord

= (Force / At) + (moment/Zt)

= (54 x 1000) / 68.4 + ((0.7X100000)/23643))

= 790 Kg/cm^2 + 3 Kg/cm^2

= 793 Kg/cm^2

Using STM analysis stress in Bottom member of bottom chord

= (Force / Ab) + (moment/Zb)

= (235 x 1000) / 131 + ((0.3X100000)/30736))

= 1794 Kg/cm^2 + 1 Kg/cm^2

= 1795 Kg/cm^2

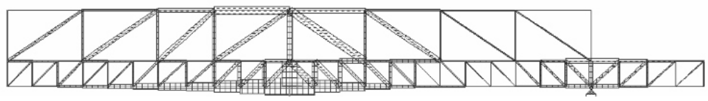

Fig 2.5 AXIAL FORCE DIAGRAM OF STM ANALYSIS

5. Finite Element Analysis (FEM)

Finite element analysis is an accurate method of analysis. It needs sophisticated software package and needs more time for modelling and interpretation of results. For precise analysis without any approximations, plate girder is simulated using plate elements. The web is divided into smaller plates by meshing the surface. Other components are modelled as frame members. Frame analysis of the rigid frame with FEM for plate girder is carried out.

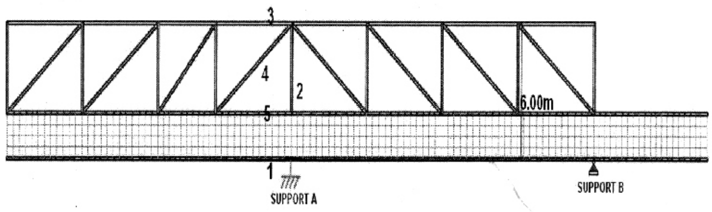

Fig 2.6 LINE DIGRAM FOR FEM ANALYSIS

From STAAD analysis

a) Axial force in Top member 3 = 106 T ;
Moment in Top member 3 = 1.0 T-M

b) Axial force in bottom member 5 = 62 T ;
Moment in bottom member 5 = 0.2 T-M

c) Axial force in bottom member 1 = 170 T ;
Moment in bottom member 1 = 1.5 T-M

d) Axial force in inclined member 4 = 58 T

Using FEM analysis, stress in top chord of entire frame

= (Force / Atop) + (Moment/Z)

= (106 x 1000) / 91.28 + ((1.0X100000)/848))

= 1162 Kg/cm^2 + 118 Kg/cm^2

= 1280 Kg/cm^2

Using FEM analysis, stress in Top flange of plate girder (bottom chord)

= (Force / At) + (Moment/Zt)

= (62 x 1000) / 68.4 + ((0.2X100000)/23643))

= 907 Kg/cm^2 + 1 Kg/cm^2

= 908 Kg/cm^2

Using FEM analysis stress in Bottom flange of plate girder (bottom chord)

= (Force / Abott.) + (Moment/Zb)

= (170 x 1000) / 131 + ((1.5X100000)/30736))

= 1298 Kg/cm^2 + 5 Kg/cm^2

= 1303 Kg/cm^2

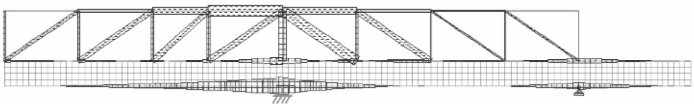

FIG 2.7 AXIAL FORCE DIAGRAM OF FEM ANALYSIS

Taking results of FEM as more accurate , it is considered as benchmark for comparison with other methods.

1) By Truss analysis, the stress in the top chord (which has a small section) is overestimated where as the stress in the bottom chord (stiff member) is very much underestimated.

2) In the frame analysis, the stress in top chord (small section) is underestimated and the stress in bottom chord (stiff member) is overestimated.

3) In the frame analysis, distribution of axial force and moments are based on the stiffness.

4) STM gives fairly accurate estimate of stresses though slightly on the conservative side.

Conclusions :

1. For simple structures, when the girder section is symmetrical about the major axis (bending axis) and top / bottom chord section has very small bending stiffness, approximate method like truss method provides reasonable results.

2. When the girder section is symmetrical and top / bottom chord section has sufficient bending stiffness, then instead of truss analysis, frame analysis will provide better results.

3. STM model can provide fast, slightly conservative and reasonable results which can be used for initial sizing of the members. FEM analysis will provide better simulation closer to the actual structure and can predict accurate stresses.

4. For unusual, unsymmetrical girder section with large variation in cross section area and bending stiffness for various members, it is difficult to predict the stresses using simple methods. Simplified methods with certain assumptions may not always give conservative results. For complex problems, the results should be cross checked using appropriate alternate methods.

Author :

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Comparison of results:

NAME OF METHOD	TOP CHORD	TOP FLANGE OF BOTTOM CHORD	BOTTOM FLANGE OF BOTTOM CHORD
	KG/CM2	KG/CM2	KG/CM2
Beam Theory (Bending)	2030	151	825
Truss Theory	2434	498	498
Frame Analysis (Single Bottom Chord)	804	2670	2397
Stm (Bottom Chord Web Model As Truss)	1527	793	1795
Fem (Bottom Chord Web Modeled As Plate Elements)	1280	908	1303

TABLE 1.0

DIFFERENT STRENGTHENING TECHNIQUES FOR RC COLUMNS

Dr. Gopal L. Rai

About FRP:

Fiber Reinforced Polymers (FRP) composites comprise fibres of high tensile strength within a polymer matrix such as vinylester or epoxy. FRP composites have emerged as a very useful engineering material following its applications during Second World War, in diverse range of applications such as aircrafts, helicopters, space-craft, satellites, ships, submarines, automobiles, chemical processing equipments, sporting goods and civil infrastructures. Role of FRP for strengthening of existing or new reinforced concrete structures is growing at a rapid pace owing mainly to the ease and speed of construction, and possibility of applications without disturbing existing function of the structure.

Present Strengthening Techniques of RC Columns:

Concrete Jacketing

Addition of a layer of concrete in the form of a jacket, reinforced with longitudinal reinforcement and transverse ties.

Additional concrete and reinforcement contribute to increase in strength.

Minimum allowable thickness of jacket = 100 mm.

With increase in sizes of the sections, free available usable space becomes less.

Considerable dead mass is added.

Stiffness of the system is increased.

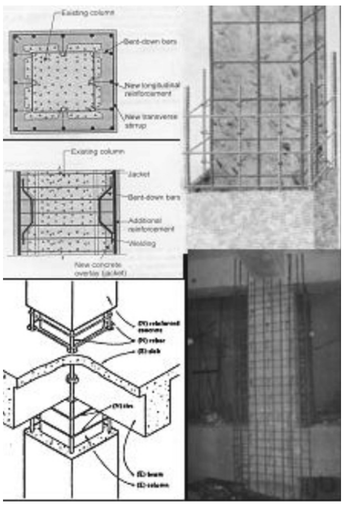
Requires adequate dowelling to the existing column.

Longitudinal bars need to be anchored to the foundation and taken continuous through the slab.

Requires drilling of holes in existing column, slab, beams and footings.

Placement of additional ties in beam column joints is not practically feasible.

Speed of the work is low.



Steel Jacketing

Encasing columns with steel plates and filling the gap with a non-shrink grout.

Provides passive confinement to core concrete.

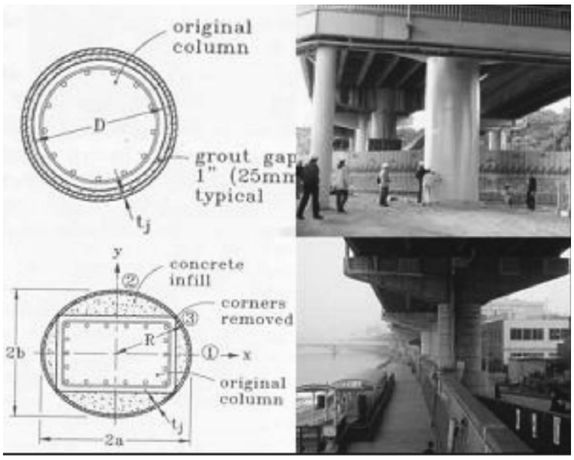
Resistance in axial and transverse direction cannot be coupled or predictably optimized.

High young's modulus of steel makes it take a large portion of the axial load resulting sometimes in premature buckling of steel.

General thickness of grout = 25 mm.

Rectangular steel jackets on rectangular columns are not generally recommended and a use of an elliptical jacket is recommended.

Since steel jacket is vulnerable to corrosion and damages due to impact with floating materials, it is not used in hydraulic structures.



Precast Concrete Jacketing

Helps in faster construction.

New longitudinal reinforcement is set around the existing column, and precast concrete segments are placed around new reinforcement.

All segments are tied together by strands.

After injecting non-shrinkage mortar between the existing concrete and precast concrete segment, prestressed force is introduced in the strands to assure the contact of the segments.

External Prestressing

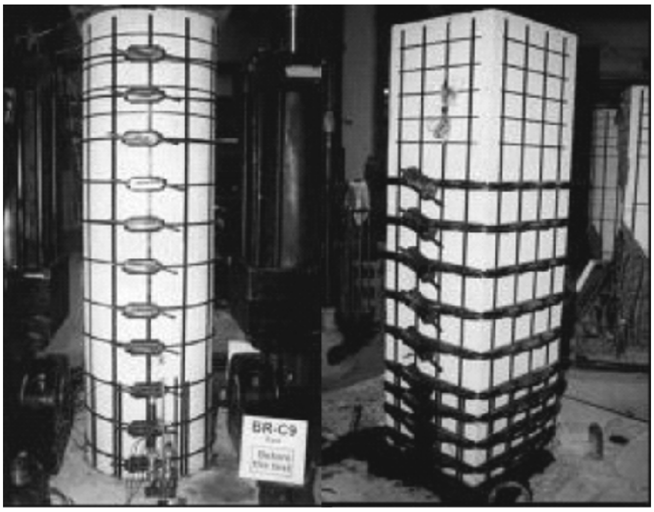
Involves prestressing the columns by external strands to provide active confinement.

It is efficient and more economical than steel jacketing.

Installation of such a system is less disturbing to occupants of building.

The technique is very recently developed and on-site implementation is not known.

Shear strength increase is only due to increase in concrete strength as against jacketing where jacket concrete contributes towards shear strength.



Strengthening of RC Columns by FRP Composites

The concept

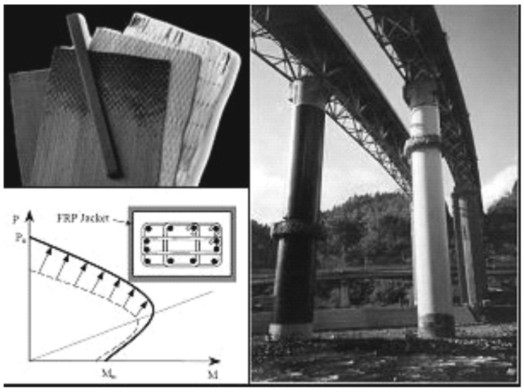
Wrapping of RC columns by high strength-low weight fiber wraps provides passive confinement, which increases both strength and ductility.

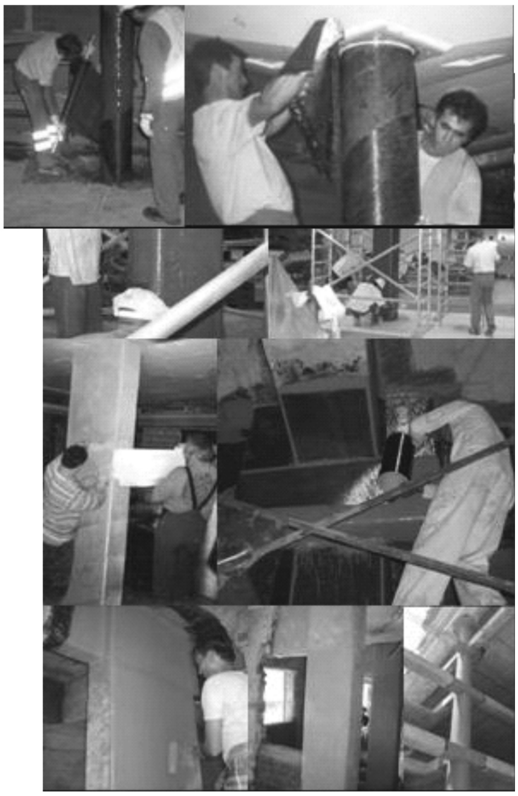
FRP sheets are wrapped around the columns, with fibers oriented perpendicular to the longitudinal axis of column, and are fixed to the column with epoxy resin.

The wrap not only provides passive confinement and increases concrete strength, but also provides significant strength against shear.

Advantages of FRP for strengthening RC columns

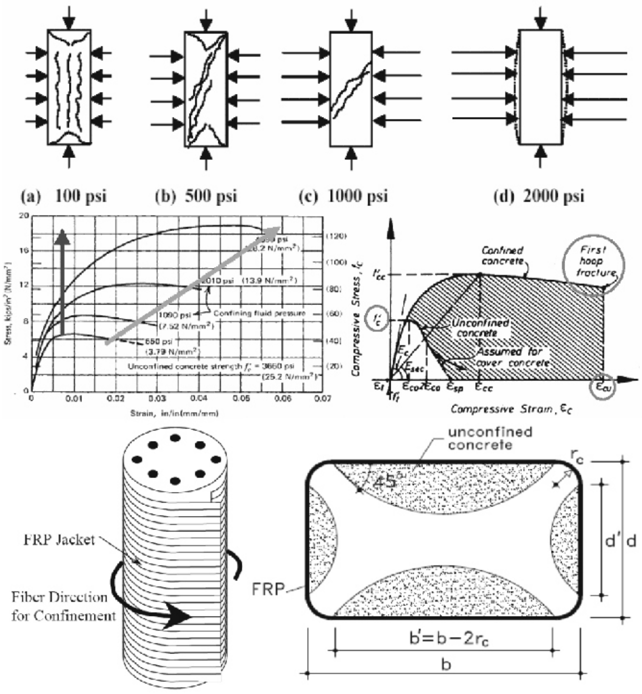
- It provides a highly effective confinement to columns.
- The original size, shape and weight of the members are minimally altered (unlike any other jacketing), thus not attracting higher seismic forces.
- Since original shape and size of the members are practically unaltered, the method is useful for strengthening heritage structures.
- Due to the orthotropy built in by fiber orientation, the wraps essentially provide only confinement without bearing the axial load which is taken completely by the concrete column as against steel jacketing, where the jacket also takes axial load and becomes susceptible to buckling.
- No drilling of holes is required as against concrete and steel jacketing.
- The FRPs have good corrosion resistance and are suitable for marine and coastal environments.
- FRP wraps prevent further deterioration of concrete and embedded reinforcement.
- As the wraps are available in long rolls, construction joints can be easily avoided.
- Ease of installation makes the use of FRP sheets cost-effective and efficient alternative in strengthening of existing buildings.
- Provides minimal disturbance to existing structure. Strengthening work can be performed without affecting the normal activities.





The Concept of Confinement

- As concrete is uniaxially compressed, Poisson's effect induces transverse strains and expansion of the concrete resulting in volumetric expansion.
- Confining the concrete with a continuous FRP jacket, the fibers resist the transverse expansion of the concrete.
- The effect of confining pressure provided by wrap induces a triaxial state of stress in the concrete, which exhibits superior behavior in both strength and ductility than concrete solely under uniaxial compression.
- Since, FRP jacket acts to contain damaged sections of concrete; the maximum usable strain level in the concrete is limited only by the ultimate strain obtainable in the FRP jacket and not by concrete crushing.
- To increase the effectiveness of wrap, the sharp edges of the rectangular sections must be rounded.



Design of FRP Strengthening

The design of FRP strengthening is done on established principles of mechanics. ACI, CEB-FIP, EuroCode and Japanese, Swedish bridge code, Chinese Standards, Turkish code give guidelines for the design of FRP system for wrapping of concrete columns to increase their capacity. Various institutes like NCHRP, Caltrans and CPWD recommend the use of FRP Composites for strengthening concrete structures.

For design of strengthening, a composite action is assumed between fiber and existing concrete and following assumptions are made:

- No slip between FRP and Concrete.
- Shear deformation within adhesive layer and tensile strength of concrete are neglected.
- FRP jacket has a linear elastic stress-strain relationship up to failure.

Corrosion protection by FRP

- Corrosion in reinforced concrete structures causes deterioration of infrastructure.
- Structures in or near marine environments are especially vulnerable.
- A widely promoted method for protecting structures in corrosive environments is the application of FRP composite wraps over the surface of the concrete elements.
- Corrosion due to chloride ingress is arrested by the prevention of further chloride contamination and penetration of oxygen and water needed to continue corrosion process.

Design Example for Strengthening of Circular Concrete Column

Let us consider a case of column strengthening. Let us design the strengthening using concrete jacketing, steel jacketing and FRP wrapping. Let

Diameter of column, D = 400 mm

Area of reinforcement, A_{sc} = 8-16Φ (1608 mm^2)

Thus, area of concrete, $A_c = \pi*400^2/4 - 1608$

$= 124055.77\ mm^2$

Grade of concrete = M15 (f_{ck} = 15 MPa)

Grade of steel = HYSD (f_y = 415 MPa)

Required: To increase the axial load capacity by 50% (1.5 times)

Existing axial load capacity, $P_u = 0.4f_{ck}A_c + 0.67f_yA_{sc}$

Thus, P_u = 0.4*15*124055.77 + 0.67*415*1608

= 1191.44 kN = 1200 kN (say)

Required axial load capacity, $P_{u,reqd}$ = 1.5*1200 = 1800 kN

Design with Concrete Jacketing

For concrete jacketing, the minimum allowable jacket thickness = 100 mm and minimum grade of concrete in jacket = M20 (at least 5MPa in excess of existing concrete grade). Let us provide a 100 mm thick jacket of M20 grade concrete.

Thus, new diameter of column = 400 + 100 + 100 = 600 mm

Area of jacket, $A_j = \pi*(600^2 - 400^2)/4$ = 157079.5 mm^2

Assuming 1% reinforcement in jacket,

Area of longitudinal reinforcement in jacket, A_{scj} = 1570.80 mm^2

Let us provide 8-16Φ bars in jacket (1608 mm^2)

Now, total area of reinforcement, A_{sc} = 1608 + 1608

= 3216 mm^2

New area of concrete in jacket, A_{cj} = 157079.5 – 1608

= 155471.5 mm^2

P_u = 0.4*15*124055.77 + 0.4*20*155471.5 + .67*415*3216

= 2882.32kN > 1800kN (OK)

Although a lesser thickness of jacket may be sufficient, from constraints of codal provisions and ease of working, the thickness cannot be reduced.

Percentage increase in weight of the column

= $100*(600^2 - 400^2)/400^2$ = 125.0%

Thus, the weight of the column has become more than twice to increase the capacity by 1.5 times.

Percentage increase in stiffness of column

= $100*(600^4 - 400^4)/400^4$ = 406.25%

Thus, the stiffness of the column has become more than five times to increase the capacity by 1.5 times.

Design with Steel Jacketing

Diameter of existing column, D = 400 mm

Minimum workable thickness of non-shrinkable grout

= 25 mm.

Therefore, jacket diameter, d_j = 450 mm

Now, $P_{u,reqd}$ = 1800 kN

The existing axial load capacity is to be increased by increasing the compressive strength of concrete by providing confinement.

The required cube strength $f_{ck,reqd}$ can be found out as

$P_{u,reqd} = 0.4f_{ck,reqd}A_c + 0.67f_yA_{sc}$

$1800*10^3 = 0.4*f_{ck,reqd}*124055.77 + 0.67*415*1608$

Thus, $f_{ck,reqd}$ = 27.26 N/mm^2

Therefore, $f'_{cc} = 0.8f_{ck,reqd}$ = 21.81 N/mm^2

And $f'_c = 0.8f_{ck}$ = 12 N/mm^2

Now, effective cylinder strength of confined concrete is

$f'_{cc} = f'_c(2.254\sqrt{(1 + 7.94f'_l/f'_c)} - 2f'_l/f'_c - 1.254)$

$21.81 = 12*(2.254\sqrt{(1 + 7.94*f'_l/12)} - 2f'_l/12 - 1.254)$

$3.072 = 2.254\sqrt{(1 + 0.6617f'_l)} - 0.1667f'_l$

Solving, we get, effective lateral confining pressure as

f_l = 1.907 N/mm^2

Considering allowable stress in steel jacket as 0.6*250 = 150 MPa and taking a factor of 0.67 (to provide for corrosion), we get,

$1.907 = 0.67*2*(0.6*250)*t_j/450$

Thus, thickness of steel jacket t_j = 4.27 mm

Let us provide a steel jacket of 5mm thickness around the column with 25mm grout between the column surface and jacket.

Percentage increase in weight of the column

Additional weight/ meter run

= 78.7(π*0.45*0.005) + 24(π*0.425*0.05)
= 2.16 kN/m

Original weight/ meter = $25*(\pi*0.40^2)/4$
= 3.14 kN/m

% weight increase = 100*2.16/3.14
= 68.78%

Thus, the increase in weight is less than that for concrete jacketing but is still very significant. We require increasing the weight by a two-third of original weight in order to increase the axial load capacity by 1.5 times.

Percentage increase in stiffness of the column

E for concrete = $5000*(15)^{0.5}$
= 19365 MPa

Initial EI = 25000

Thus, the increase in weight is less than that for concrete jacketing but is still very significant. We require increasing the weight by a two-third of original weight in order to increase the axial load capacity by 1.5 times.

Design by FRP Wrapping

As calculated in previous section, effective confining pressure required

f'_l = 1.907 N/mm^2

For S&P C-Sheet 240, we have, ultimate tensile strength, f_{fu} = 3800 MPa

Assuming only 50% strength development, we have,

1.907 = 2*(0.5*3800)*t_j/400

which gives, required jacket thickness, t_j = 0.201 mm

Let us provide one layer of 430 gsm S&P C-Sheet jacket (t_j = 0.234mm) around the column.

Weight density of fiber = 17 kN/m^3

Additional weight per meter run due to fiber
= 17(π*0.4*0.000176)
= 0.00376 kN/m

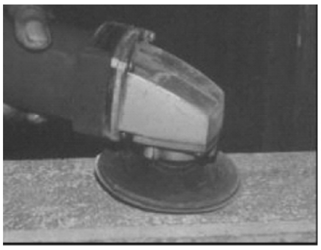
Original weight per meter
(as calculated in previous section) = 3.14 kN/m

% weight added to the column = 100*0.00376/3.14
= 0.12% (Negligible!). Therefore, we can say that, there is a negligible mass increase in column due to fiber wrapping

Onsite Application of FRP Wrapping

A proper application procedure involves following steps:

1. Surface preparation includes:
   a. Grinding to a smooth column surface.
   b. Repair of hairline cracks, if any.
   c. Rounding off of column corners to specified radius Application of Primer

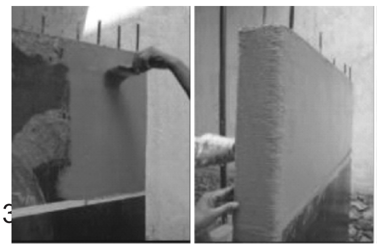


Grinding the concrete surface

Repair of hairline cracks

2. Once the surface is prepared and primer dried, the next step is application of saturant.

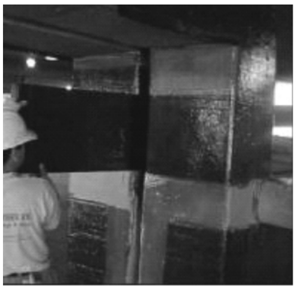
3



Application of Saturant

Wetting of wrap with saturant

4. Fiber is then wrapped on the column uniformly so that there are no undulations in the wrap.

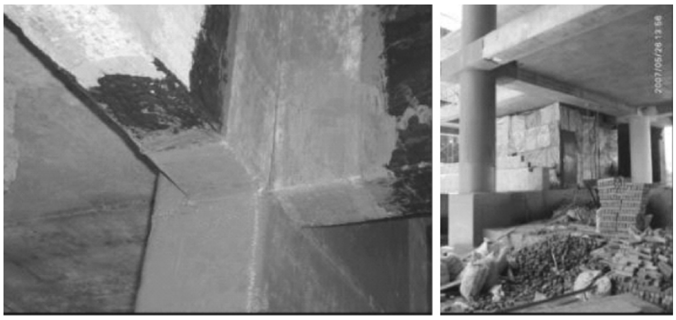


Wrapping with Carbon Fiber

Wrapping with Glass Fiber

5. After wrapping, the fiber is again wetted with one more layer of saturant to make sure that the fiber is soaked fully with saturant.

Application of Saturant on FRP Wrapping



RC Columns after Completion of FRP Wrapping

Conclusion with Comparison

Description	Concrete Jacketing	Steel Jacketing	FRP Wrapping	Remarks
Mode of strengthening	Increase in concrete and steel area	Confinement	Confinement	
Preparation of column for strengthening	Significant dismantling of cover concrete. At least 40 mm cover concrete to be removed. Epoxy primer to be applied on exposed surface.	No major dismantling work involved. Mainly plaster to be removed and epoxy primer to be applied on exposed surface.	Only plaster to be removed and epoxy primer to be applied on exposed surface. For rectangular columns, corners to be rounded off.	FRP involves minimum surface preparation.
Drilling of holes	Large amount of drilling is required	Large amount of drilling is required	No drilling required	FRP involves minimum work since no drilling is required.
Additional weight	In example shown, the weight becomes 225% for just 50% increase in strength	In example shown, the weight becomes 169% for 50% increase in strength.	Negligible. No increase in weight at all.	FRP hardly increase the dead weight of the structure
Size Increase	In example shown, the diameter of column increases from 400mm to 600mm for 50% increase in strength.	In example shown, the diameter of column increases from 400mm to 450mm for 50% increase in strength.	Negligible. The total increase in diameter is less than 5 mm.	The sizes almost remain unaltered thus retaining same the free area.

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He can be reached at gopalrai@sp-india.com

A LETTER OF PROTEST

Vide press reports dated 15.03.2009, the Indian government has exempted 3 crucial steel items used in construction industry 'TMT bars, Structural Steel and Tin plates' from the list of mandatory quality control order by the Bureau of Indian Standards. This simply means that now the manufacturers of reinforcement bars need not subject their rebars to quality tests and need not produce test certificates. This is likely to result into supply of inferior quality rebars in market, which in turn may lead to construction of unsafe structures. ISSE has written to the Ministry of Steel, Government of India expressing deep concern and protest against this decision. The letter of protest is given below.

April 13, 2009

Shri P.K. Rastogi
Secretary, Ministry of Steel Government of India
Udyog Bhavan, Maulana Azad Marg, New Delhi 110 011
Fax No: 011-23063236

Dear Sir

Ref: Press note dated 15.03.2009: “India removes rebars, sections and tin plates from quality control order”

Sub: A protest and an appeal to withdraw

From the press reports of 15.03.2009, we understand that the Indian government has exempted 3 crucial steel items used in construction industry 'TMT bars, Structural Steel and Tin plates' from the list of mandatory quality control order by the Bureau of Indian Standards.

It is surprising and highly disturbing that the ministry of steel has withdrawn the condition of compulsory certification of quality of steel by the Bureau of Indian Standards. Although you yourself claim to believe that it is necessary to have certification of steel, your action on these conditions is baffling and undermines the basic tenets of quality control/ assurance. We also understand that your action is based on the grounds that over 50% of the production in steel is produced by secondary producers who are not equipped (?) to go for mandatory norms of testing. Would this not virtually amount to an encouragement and license to spurious steel manufacturers to produce substandard steel?

As a matter of fact, steel is one of the two most important construction materials which impart strength, stability, durability and earthquake resistance to the structures which are constructed. It is also important to note that the quality of steel which comes to construction sites is the quality with which it is manufactured, which means that its quality cannot be enhanced during construction. On this background we are surprised that instead of making its quality control norms more stringent you are diluting them. Please note that in our professional experience, we have often come across inferior quality steel despite the condition of certification. Then what would be the fate of our structures if the condition of certification of steel is removed? We have no doubt that this step of yours would lead to construction of substandard quality structures in India and a sure recipe for disaster.

We are also perplexed about the inherent contradictions in the actions of our government offices. On one hand the government talks about taking our country forward (on par with the most advanced countries), improving quality of structures by making our National Codes mandatory, mitigating disasters etc and on the other hand some policy makers are diluting the basic quality tenets which have existed for many years. As professionals, we find this demoralizing and frustrating. Would you take the responsibility if lives and property are lost on account accidents/ collapse of structures due to substandard quality? Please note that many structures failed during Gujarat earthquake of 2001 due to sub-standard quality of steel being used in the structures.

If you remove such important conditions having enormous bearing on structural stability, how can professionals (structural engineers, architects etc) certify the structures constructed with our professional services to be safe and stable. Would you/ the government remove such requirements of professional certification also?

We appeal to you to understand the serious and undesirable implications of withdrawing an already existing condition of compulsory certification of quality of steel and to withdraw this circular. If some manufacturers are not equipped (may be they are “not willing” rather than “not equipped”) they should get that capability if they are to be recognized as manufacturers of such an important construction material. They should raise their quality norms rather than our government relaxing current norms to suit such manufactures. If quality control norms are diluted in this manner just because some vendors are “not equipped” to comply with conditions of certification, there is no doubt that “quality” will go for a toss and manufacturers of good quality materials will lose out to unfair practices. We think it is our moral duty that we should never allow this.

In the light of the above analysis, we would rather request you to make such conditions even more stringent. At least we should insist that the mechanical properties of steel produced are in conformity with the respective Indian Standards specifications and that the manufacturer's name must be embossed on the steel bar at every meter length.

In this regard if you need our assistance, Indian Society of Structural Engineers will be more than willing to provide the same in the interest of our nation.

Thanking You,

Yours Faithfully

For Indian Society of Structural Engineers (ISSE)

Advisory Trustees

PRODUCT REVIEW

We have now introduced a new section, "Product Review" into the ISSE journal. This is where manufacturers and dealers can introduce their products such as construction materials, chemicals, equipment, software etc, through a technical review. Only one product review may be printed in each issue. A space of up to two pages of the journal may be allocated to this feature.

The main purpose of this feature is to introduce the newer products available in the market to our readers, and therefore, the review should be technically intensive. The manufacturers and dealers can highlight the advantages and uniqueness of the featured products in the review.

The review should cover one or two products only and may include their technical specifications, method of installation/ application, available product range, unique features, advantage, photographs etc. It should not be a direct commercial promotion of the products. However, the contributor may include his contact details at the end of the review. Matter received may be suitably edited and modified in consultation with the contributor.

For details please call the editor.

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We earnestly request you to visit www.isse.org.in and update your particulars as soon as possible so that you do not miss the Journal or important announcements.