6th GRIHA Conference and Exhibition on "Accelerating Sustainability in Built Environment" on 3rd & 4th February,2015

Technical Session ***"Structural Systems and Construction Technologies for Green Buildings"***

<u>*Structural Design Aspects for Green Buildings*</u>

by

S. C. Mehrotra

Chairman Membership Committee – FIDIC (International Federation of Consulting Engineers

Immediate Past - President Indian Association of Structural Engineers

Past President – Consulting Engineers Association of India

Chief Executive & Principal Structural Design Consultant

Mehro Consultants

THE ISSUE

- **SUSTAINABLE DEVELOPMENT IS THE ISSUE OF THE 21ST CENTURY**

- **WHETHER WE LIKE IT OR NOT, OUR SOCIETY WILL HAVE TO DEAL WITH THIS ISSUE DURING THE CENTURY**

A PREREQUISITE FOR THE SUCCESSFUL ACHIEVEMENT OF SUSTAINABLE DEVELOPMENT IS THE CREATION OF AN ENVIRONMENT FOR INNOVATION.

WE HAVE TO ENCOURAGE AND TRY OUT NEW APPROACHES, TEST NEW TECHNOLOGIES, AND REPLACE OLD WAYS WITH NEW AND MORE SUSTAINABLE ALTERNATIVES.

BUILDING STRUCTURE ASPECTS

THE COST OF STRUCTURE OF A BUILDING IS APPROXIMATELY EQUIVALENT TO COMBINED COST OF ELECTRICAL, MECHANICAL VENTILATION AND PLUMBING. THUS THERE IS GREATER NEED TO CONSIDER ENERGY SAVING IN STRUCTURAL DESIGN & CONSTRUCTION OF A BUILDING.

A STRUCTURE IS SUBJECTED BOTH TO VERTICAL LOADS LIKE DEAD LOADS, IMPOSED LOADS ETC. AND LATERAL LOADS LIKE EARTHQUAKE, WIND ETC.

IT IS NOT POSSIBLE TO DESIGN EARTHQUAKE PROOF STRUCTURE AS WE CAN NOT CATER FOR LARGE EARTHQUAKE FORCES. WE DESIGN FOR A FRACTION OF ACTUAL EARTHQUAKE FORCES WHICH A STRUCTURE CAN EXPERIENCE DURING LIFE TIME OF A STRUCTURE.

THOUGH WE HAVE FACTORS OF SAFETY WHEN WE DESIGN FOR DEAD LOADS, IMPOSED LOADS AND WIND LOADS BUT FOR EARTHQUAKE WE CATER FOR A PART ONLY AND DESIGN AS EARTHQUAKE RESISTANT STRUCTURE.

MCE: -

MAXIMUM CONSIDERED EARTHQUAKE IS THE MOST SEVERE EARTHQUAKE EFFECTS CONSIDERED BY THE INDIAN STANDARD CODE 1893 (PART 1) : 2002. (CRITERIA FOR EARTHQUAKE RESISTANT DESIGN OF STRUCTURES)

DBE: -

DESIGN BASIS EARTHQUAKE IS THE EARTH QUAKE WHICH CAN REASONABLY BE EXPECTED TO OCCUR AT LEAST ONCE DURING THE DESIGN LIFE OF THE STRUCTURE.

DBE = ½ MCE

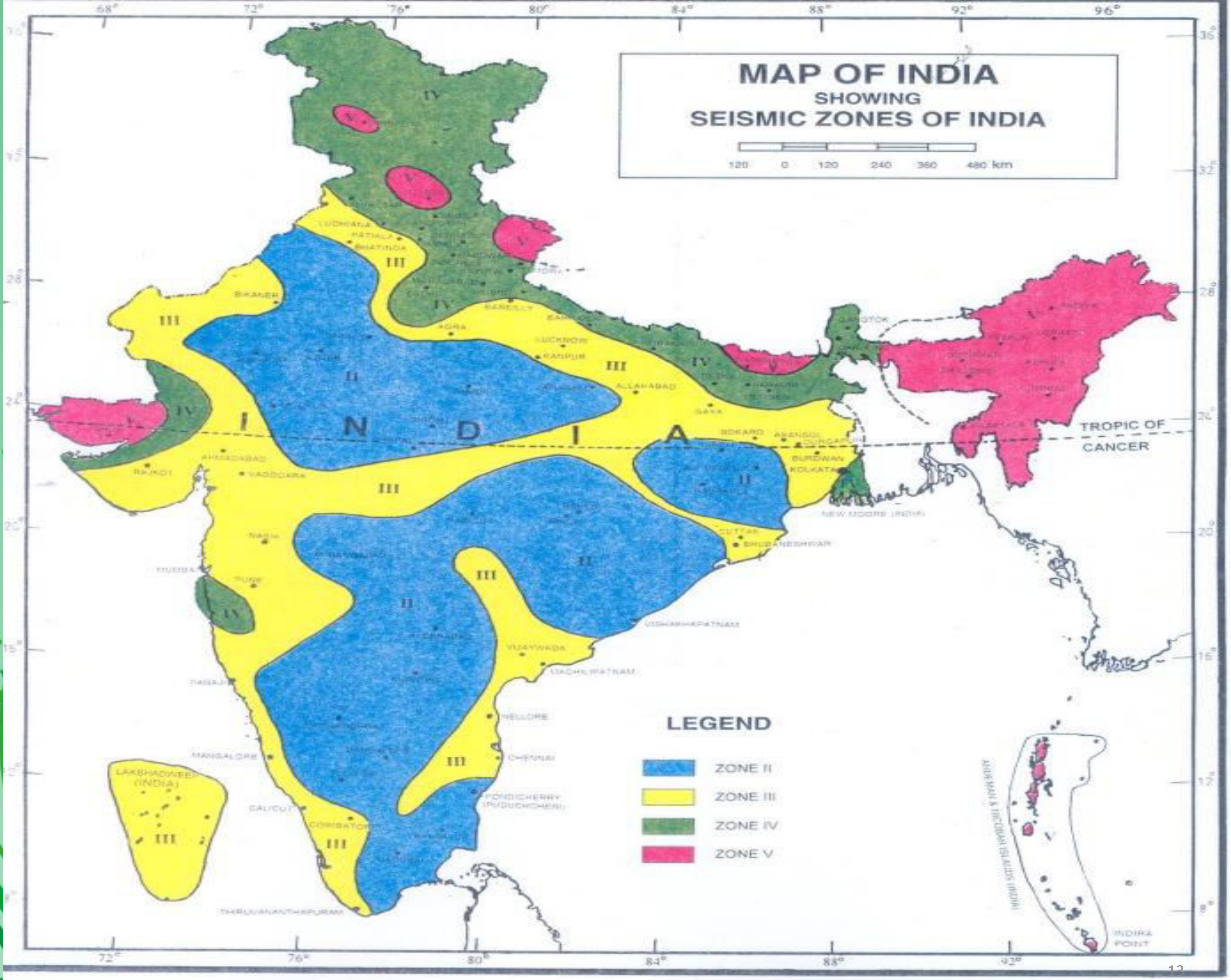
INDIAN STANDARD CODE SPECIFIES THE DESIGN HORIZONTAL SEISMIC COEFFICIENT A_H FOR A STRUCTURE BY THE FOLLOWING EXPRESSION:

$$A_H = \frac{Z\,I}{2\,R}\,\frac{SA}{G}$$

R = RESPONSE REDUCTION FACTOR

Z = ZONE FACTOR IS FOR THE MAXIMUM CONSIDERED EARTHQUAKE (MCE) AND SERVICE LIFE OF STRUCTURE IN A ZONE.

THE FACTOR 2 IN THE DENOMINATOR OF Z IS USED SO AS TO REDUCE THE MAXIMUM CONSIDERED EARTHQUAKE (MCE) ZONE FACTOR TO THE FACTOR FOR DESIGN BASIS EARTHQUAKE (DBE).



NOTE : Towns falling at the boundary of zones demarcation line between two zones shall be considered in High Zone.

THUS IT MAY BE HIGH-LIGHTED HERE THAT AS PER IS CODE WE ARE DESIGNING FOR ONLY 10% OF MAXIMUM CONSIDERED EARTHQUAKE (DESIGN BASIS EARTHQUAKE = ½ MAXIMUM CONSIDERED EARTHQUAKE AND RESPONSE REDUCTION FACTOR CONSIDERED FOR SPECIAL RC MOMENT RESISTING FRAME IS 5).

THUS, WE DEPEND HEAVILY ON DUCTILITY OF THE STRUCTURE.DUCTILITY OF A STRUCTURE OR ITS MEMBER IS THE CAPACITY TO UNDER GO LARGE INELASTIC DEFORMATION WITHOUT SIGNIFICANT LOSS OF STRENGTH.

AS PER IS 1893 (PART 1) 2002 (CRITERIA FOR EARTHQUAKE RESISTANT DESIGN OF STRUCTURES). THE DESIGN APPROACH ADOPTED IN THE STANDARD IS TO ENSURE THAT STRUCTURES POSSESS AT LEAST A MINIMUM STRENGTH TO WITHSTAND MINOR EARTHQUAKE, WHICH OCCUR FREQUENTLY WITHOUT DAMAGE

RESIST MODERATE EARTHQUAKE WITHOUT SIGNIFICANT STRUCTURAL DAMAGE THOUGH SOME NON-STRUCTURAL DAMAGE MAY OCCUR AND STRUCTURES WITHSTAND A MAJOR EARTHQUAKE WITHOUT COLLAPSE, THOUGH THERE MAY BE SERIOUS DAMAGES TO BEAMS AND COLUMNS BUT STRUCTURAL SYSTEM DOES NOT COLLAPSE.

ATTRIBUTES TO PERFORM WELL DURING AN EARTHQUAKE ARE:

1. **ADEQUATE LATERAL STRENGTH, STIFFNESS AND DUCTILITY.**

2 **SIMPLE AND REGULAR CONFIGURATION IN PLAN AND ELEVATION. IF IN ARCHITECTURAL PLANNING STAGE, THE ADOPTED PLAN HAS IRREGULARITY IN PLAN OR ELEVATION, *ENERGY REQUIREMENT* WOULD INCREASE BECAUSE OF LARGER REQUIRED SIZES OF STRUCTURAL ELEMENTS.**

USE OF CELLULAR LIGHT WEIGHT CONCRETE BLOCKS

CLC (CELLULAR LIGHT WEIGHT CONCRETE) BLOCKS ARE SUBSTITUTE TO BRICKS AND CONVENTIONAL CONCRETE BLOCKS IN BUILDING WITH DENSITY VARYING 600 – 1000 KG/M^3. THE NORMAL CONSTITUENTS OF THIS ARE CEMENT, FLY ASH, SAND, WATER AND FOAMING AGENT.

ADVANTAGES OF CLC BLOCKS

REDUCTION OF DEAD LOAD RESULTING IN LESSER VERTICAL LOADS, LESSER EARTHQUAKE FORCES AND THUS RESULTS INTO SAVING OF STEEL AND CEMENT.

IT ALSO REDUCES LATERAL DEFLECTION UNDER EARTHQUAKE FORCES AND THUS REDUCES HUMAN DISCOMFORT DURING AN EARTHQUAKE.

IS 456:2000 ALLOWS USE OF PORTLAND POZZOLANA CEMENT (FLY ASH BASED) CONFORMING TO IS 1489 (PART I)

- **AS PER AMENDMENT NO. 3, JULY 2002, TO IS 1489 (PART I) 1991.**
- **"THE FLY ASH SHALL NOT BE LESS THAN 15 PERCENT AND NOT MORE THAN 35 PERCENT BY MASS OF PORTLAND POZZOLANA CEMENT."**

ORDINARY PORTLAND CEMENTS ARE AVAILABLE IN THREE GRADES (ALL PERMITTED BY IS 456)

- (I) 33
- (II) 43
- (III) 53

HOWEVER PORTLAND POZZOLANA CEMENT IS EQUIVALENT TO GRADE 33 ONLY (IS 1489 (PART I)

IF WE USE OPC OF HIGHER GRADE SAY 43 OR 53 FOR PRODUCTION OF CONCRETE ALONG WITH 25% REPLACEMENT BY FLY ASH, THE ENERGY SAVING CAN BE VERY LARGE AS COMPARED TO USING PORTLAND POZZOLANA CEMENT.

FURTHER WITH EFFICIENT CONCRETE MIX DESIGN USING SUITABLE ADMIXTURE, THIS ENERGY SAVING CAN BE INCREASED FURTHER.

IN CASE OF RCC COLUMN, USE OF HIGHER GRADE CONCRETE (M30, M35, M40 ETC.) CAN RESULT IN TO LESSER VOLUME OF CONCRETE OR LESSER REINFORCEMENT WHICH CAN FURTHER REDUCE THE ENERGY REQUIREMENT.

USE OF HIGH GRADE REINFORCING STEEL

A STUDY WAS CARRIED AND CONCLUDED THAT SUBSTANTIAL SAVING CAN BE ACHIEVED BY USING FE 500 GRADE REINFORCEMENT INSTEAD OF FE 415. THIS SAVING PERCENT VARIES FOR DIFFERENT COMPONENT OF STRUCTURES LIKE COLUMNS, BEAMS & SLABS. THE PRICE DIFFERENCE BETWEEN FE415 & FE500 IS NEGLIGIBLE.

EFFICIENT USE OF STRUCTURAL STEEL

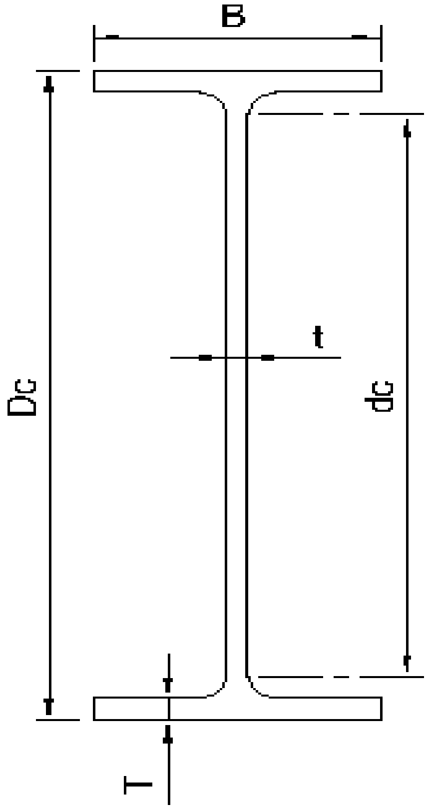
- **EFFICIENT USE OF STRUCTURAL STEEL CAN REDUCE ENERGY REQUIREMENT CONSIDERING LIFE CYCLE COST.**

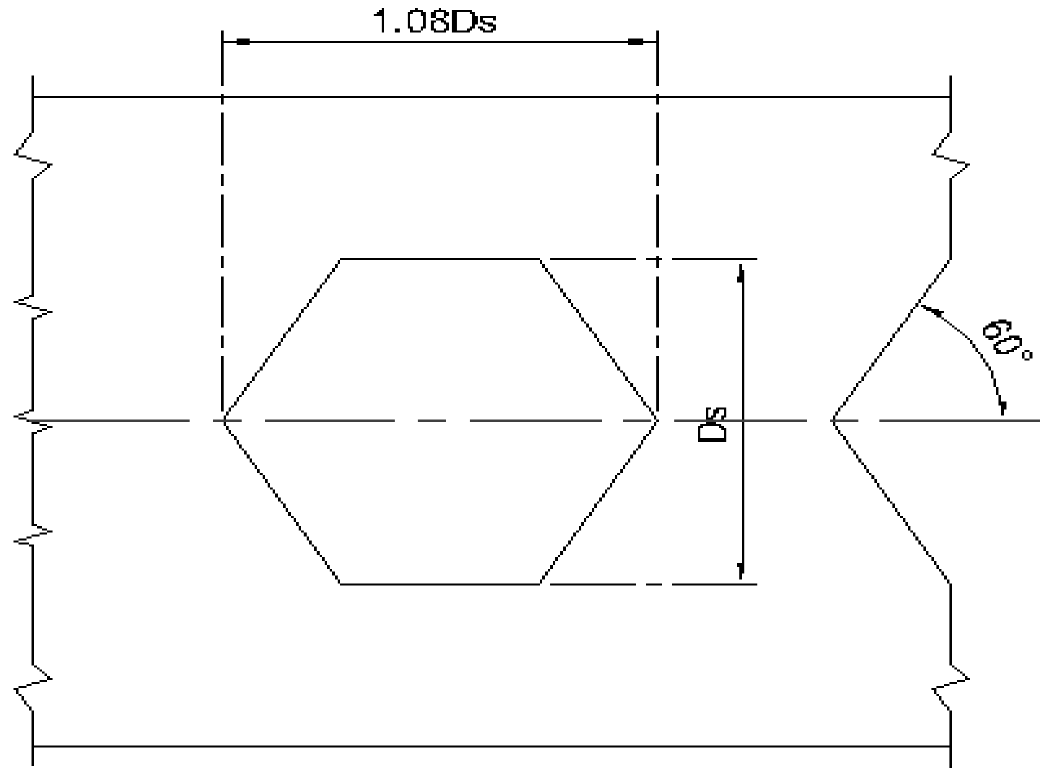
WITH RECENT INTRODUCTION OF HOLLOW SQUARE AND RECTANGULAR SECTIONS IN PLACE OF ISMB SECTIONS, WE CAN REDUCE THE ENERGY REQUIREMENTS.

BY SELECTING APPROPRIATE TECHNOLOGY, THE CONSTRUCTION CAN BE DONE FASTER WITH THE USE OF STRUCTURAL STEEL MEMBERS.

USE OF CASTELLATED BEAMS ALSO REDUCE STEEL CONSUMPTION.

ANOTHER EFFICIENT OPTION IS TO USE STEEL CONCRETE COMPOSITE CONSTRUCTION.





Serial Size	
Original	Castellated
mm	mm
914 x 305	1371 x 305
610 x 178	915 x 178
457 x 191	686 x 191

INTEGRATION OF CONCEPTS IS IMPORTANT

BYE-LAWS ASK FOR MORE PARKING. THIS IS FURTHER ENHANCED BY APPROVING AUTHORITIES. TO INTEGRATE PARKING IN THE BUILDING DESIGN, THE CLIENTS/ARCHITECTS HAVE TO DESIGN THREE LEVEL BASEMENTS. PLACES WHERE WATER TABLE IS HIGH, RESULTS IN PUMPING OUT THE WATER TO DRAINS.

THIS IS NOT AT ALL SUSTAINABLE

FURTHER ENERGY REQUIREMENT IS INCREASED DUE TO PROVISION OF SHEET PILES OR DIAPHRAGM WALL REQUIRED TO HOLD EARTH AT THE PERIPHERY OF BASEMENT DURING EXCAVATION OF BASEMENT.

USE OF NEW CONSTRUCTION TECHNOLOGIES

A NUMBER OF NEW CONSTRUCTION TECHNOLOGIES HAVE BEEN INTRODUCED IN VARIOUS COUNTRIES WHICH REQUIRE LESSER ENERGY DURING CONSTRUCTION.

USE OF FRICTION DAMPER

DUCTILITY PROVISIONS – RELIANCE FOR SURVIVAL IS PLACED ON THE DUCTILITY OF THE STRUCTURE TO DISSIPATE SEISMIC ENERGY WHILE UNDERGOING LARGE INELASTIC DEFORMATION

LESSONS LEARNT FROM RECENT EARTHQUAKES:

- **IN MODERN BUILDING, AVOIDANCE OF STRUCTURAL COLLAPSE ALONE IS NOT ENOUGH.**

- **THE COST OF NON-STRUCTURAL COMPONENTS IS MUCH HIGHER THAN THE COST OF THE STRUCTURE ITSELF AND MUST BE PROTECTED.**

- **THE ENERGY REQUIRED FOR RESTORATION OF DAMAGED NON-STRUCTURAL COMPONENTS LIKE PARTITION WALLS, FALSE CEILING, SERVICES, PIPES, FLOORING ETC. DURING EARTHQUAKE IS VERY LARGE**

ALTERNATE SOLUTION:

- **ESTABLISH PERFORMANCE BASED DESIGN CRITERIA.**
- **DISSIPATE SEISMIC ENERGY MECHANICALLY.**

IN TYPICAL STRUCTURE WITHOUT DAMPERS, THE INHERENT DAMPING IS MERELY 2-5% OF CRITICAL WITH THE INTRODUCTION OF SUPPLEMENTAL DAMPING OF 10-20% OF CRITICAL, THE FORCES AND DEFORMATIONS ON THE STRUCTURE CAN BE SIGNIFICANTLY REDUCED.

MULTIPLYING FACTORS FOR OBTAINING VALUES FOR OTHER DAMPING (IS 1893 (PART 1) : 2002) TABLE NO. 3

Damping Percent	0	2	5	7	10	15	20	25	30
	↓	↓	↓	↓	↓	↓	↓	↓	↓
Factors	3.20	1.40	1.00	0.90	0.80	0.70	0.60	0.55	0.50

PUTTING BRAKES TO EARTHQUAKE

OF ALL THE METHODS SO FAR AVAILABLE TO EXTRACT KINETIC ENERGY FROM A MOVING BODY, THE MOST WIDELY ADOPTED IS UNDOUBTEDLY THE FRICTION BRAKE. MECHANICAL ENGINEERS HAVE SUCCESSFULLY USED THIS CONCEPT FOR CENTURIES TO STOP THE MOTION OF EQUIPMENT, AUTOMOBILES, RAILWAY TRAINS, AIRPLANES, ETC.

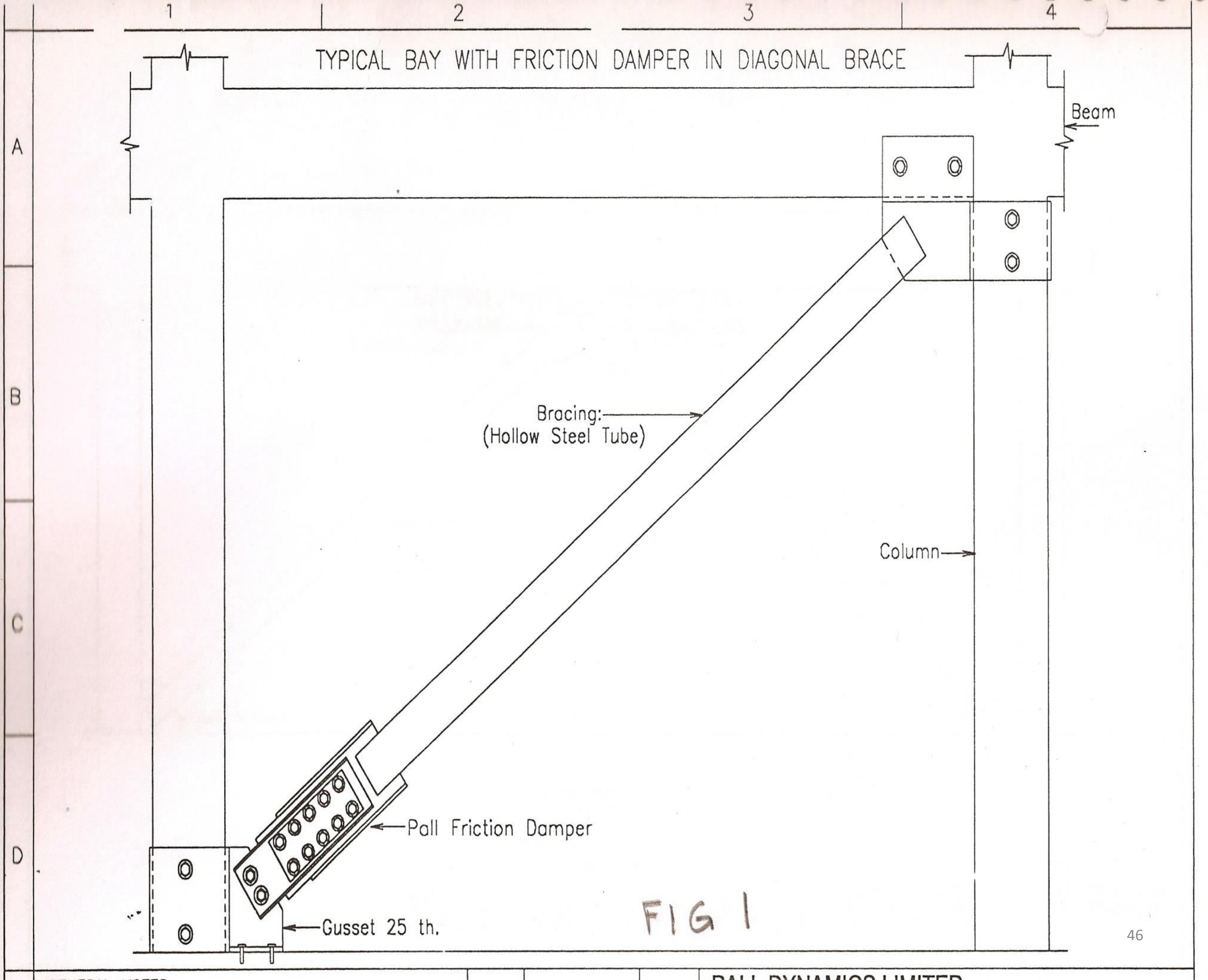
SIMILAR TO AUTOMOBILES, THE MOTION OF VIBRATING BUILDING CAN BE SLOWED DOWN BY DISSIPATING SEISMIC ENERGY IN FRICTION.

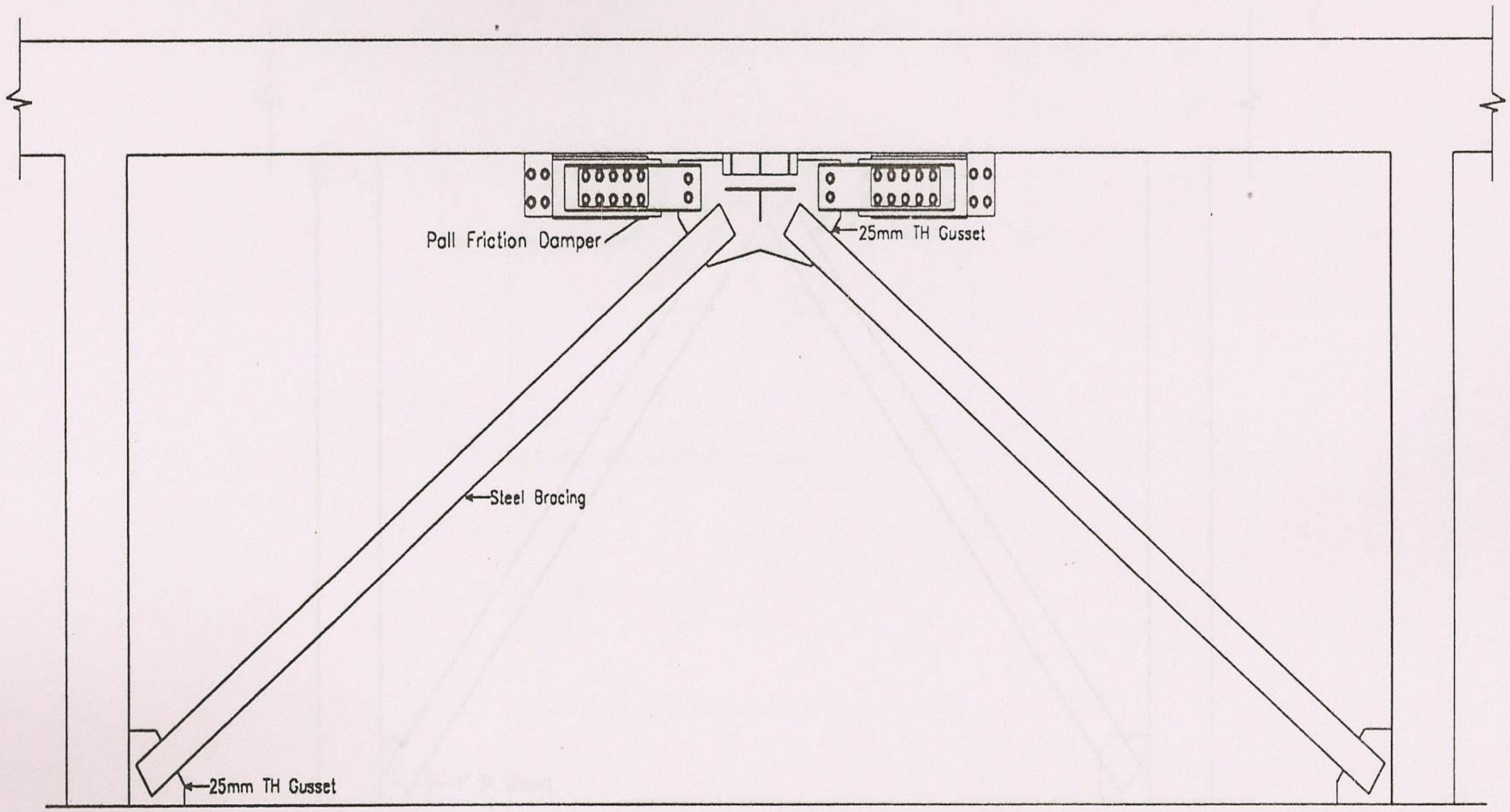
NATIONAL EARTHQUAKE HAZARDS REDUCTION PROGRAM (NEHRP) U.S.A. GUIDELINES REQUIRE THAT FRICTION DAMPERS ARE DESIGNED FOR 130% MCE DISPLACEMENT.

PALL FRICTION DAMPERS CONSIST OF SERIES OF STEEL PLATES, WHICH ARE SPECIALLY TREATED TO DEVELOP VERY RELIABLE FRICTION. THESE PLATES ARE CLAMPED TOGETHER AND ALLOWED TO SLIP AT A PREDETERMINED LOAD.

CENTRAL PLATES FOR IN-LINE FRICTION DAMPERS BEING FABRICATED.

FRICTION DAMPERS AFTER PAINTING.

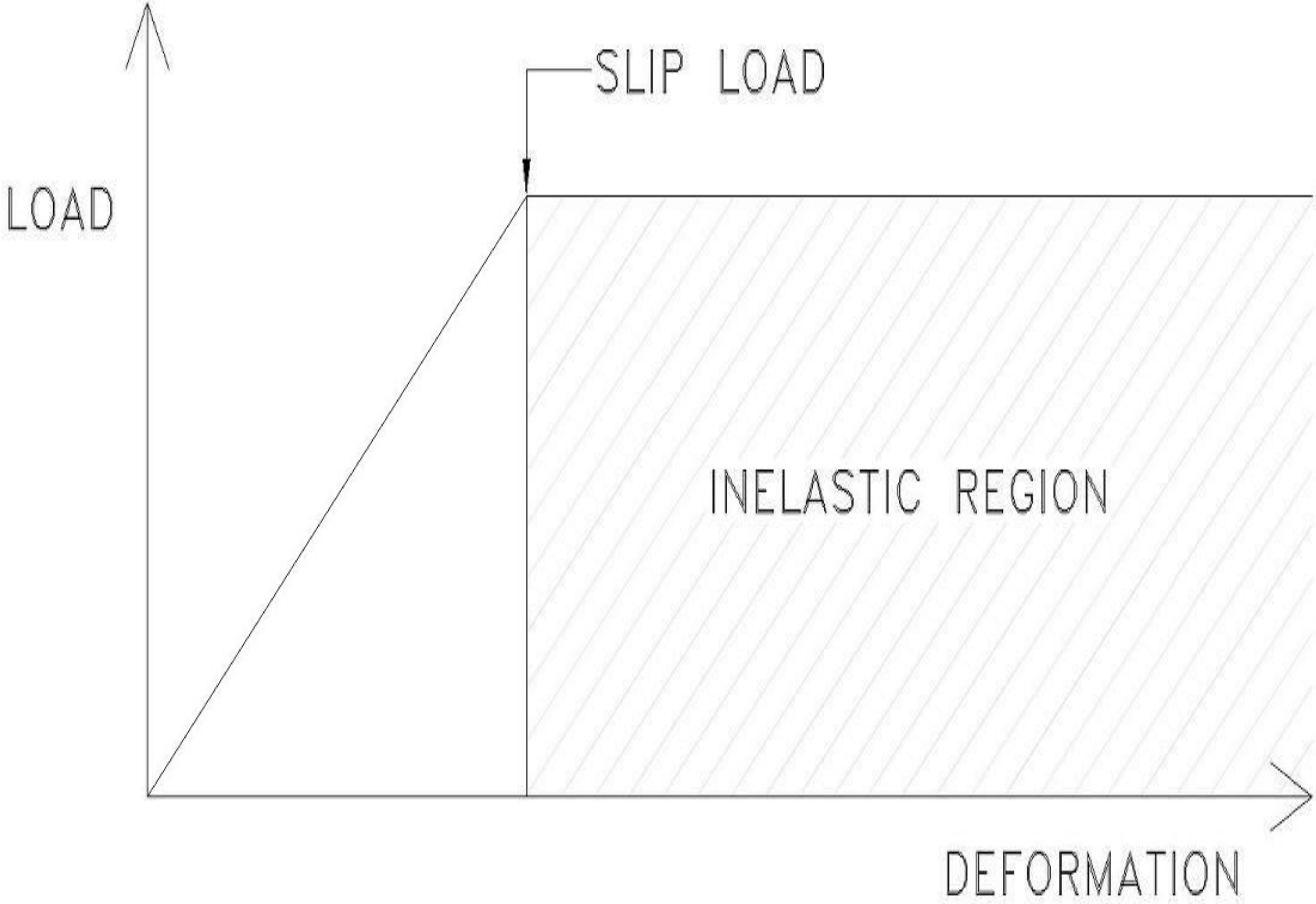

1
2
3
4
A
B
C
D
TYPICAL BAY WITH FRICTION DAMPER IN DIAGONAL BRACE
Beam
Bracing:
(Hollow Steel Tube)
Column
Pall Friction Damper
Gusset 25 th.
FIG 1



ELEVATION

FIG. 2

FRICTION DAMPER IN CHEVRON BRACE


SLIP LOAD
LOAD
INELASTIC REGION
DEFORMATION

QUEBEC PROVINCIAL POLICE HQ BUILDING, MONTREAL

UNITECH'S GARDENIA COMPLEX, GURGAON, INDIA

PALL FRICTION DAMPERS ARE COST EFFECTIVE IN DEVELOPING COUNTRIES


02.03.2009 15:24


02.03.2009 15:29

USE OF FRICTION DEMPER REDUCE REINFORCING STEEL BY 20% SINCE THEY ARE NOW MANUFACTURING IN INDIA WITH CANADIAN COLLABORATION. THEY RESULT IN ECONOMY.

NORMAL STRUCTURE DESIGN CATERS FOR 10% OF MAXIMUM CONSIDERED EARTHQUAKE (MCE) BUT WITH USE OF FRICTION DAMPERS WE CATER FOR 130% OF MCE.

PRECAST CONCRETE TECHNOLOGY

PRECAST CONCRETE TECHNOLOGY IS BEING EXTENSIVELY USED IN BUILDINGS IN A LARGE NUMBER OF DEVELOPED COUNTRIES. IN INDIA THERE IS TREMENDOUS DEMAND OF HOUSING SPECIALLY LOW COST HOUSING FOR LOWER AND MIDDLE INCOME GROUPS. PRECAST HOUSING CAN CATER FOR THIS LARGER DEMAND

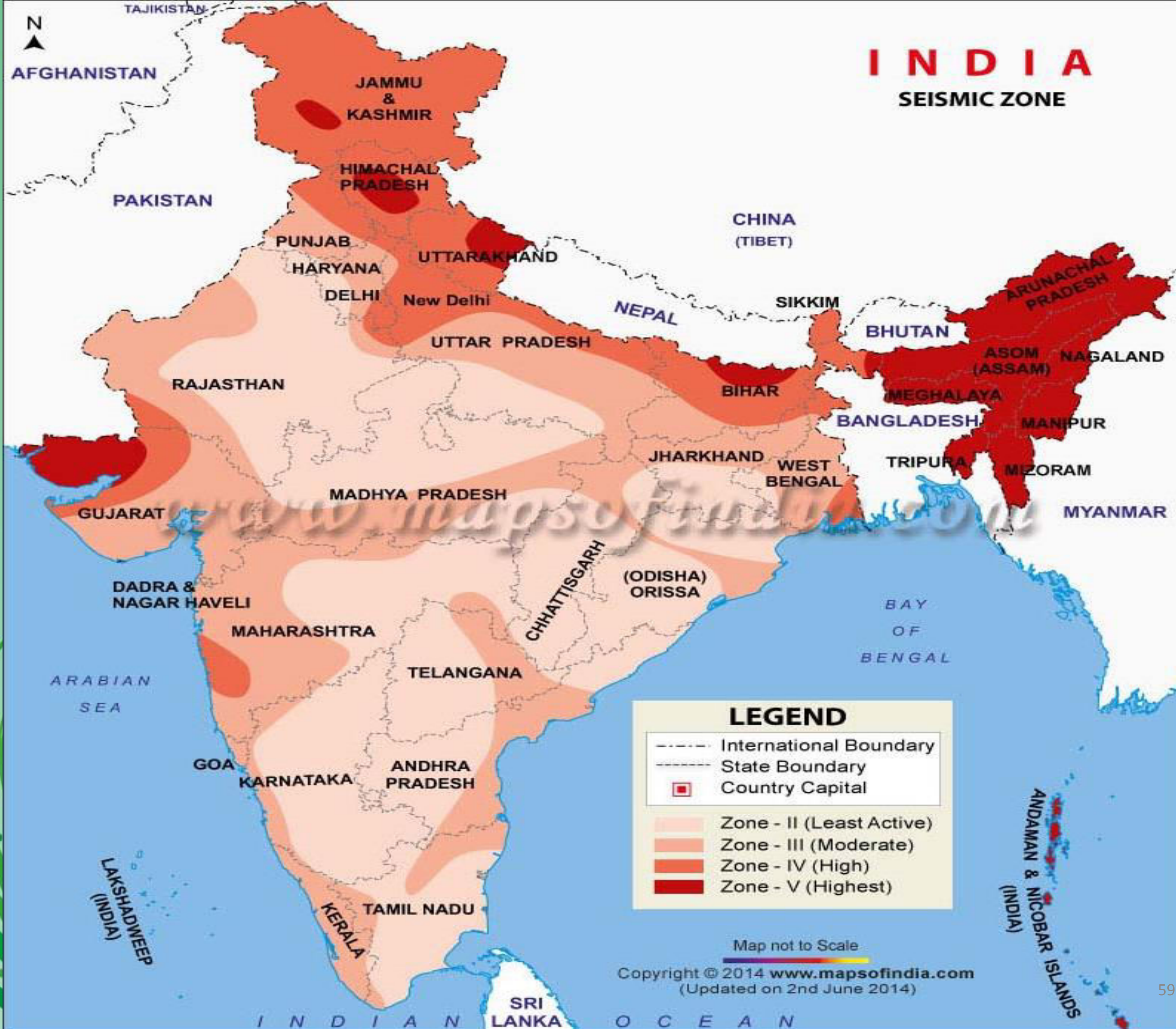
PRECAST HAS LOT OF ADVANTAGES INCLUDING FASTER CONSTRUCTION, CONTROLLED QUALITY AND THUS RESULTS IN LESSER MATERIAL CONSUMPTION AND THEREFORE SAVES ENERGY,

BUT WE HAVE LOT OF CONSTRAINTS SOME OF THEM ARE:

A) CONTINOUS SOURCE OF RAW MATERIALS CEMENT, COARSE AND FINE AGGREGATES, ADMIXUTURE ETC., POWER SUPPLY AND PRODUCTION RESOURCES.

B) COMPREHENSIVE PREPARATION OF LARGE CONSTRUTION SITE FOR MASS PRODUCTION.

C) INDIA IS PRONE TO SEISMIC ACTIVITY WE HAVE FOUR SEISMIC ZINES (II, III, IV & V) THE SOLUTION FOR A PROJECT IN BANGALORE ZONE II WILL NOT WORK FOR DELHI, GURGAON, GHAZIABAD, NOIDA (ZONE IV) IN VIEW OF SERVERE EARTHQUAKE WHICH WOULD REQUIRE ADDITIONAL EARTHQUAKE RESISTING ELEMENTS LIKE SHEAR WALLS ETC.


INDIA
SEISMIC ZONE
N
TAJIKISTAN
AFGHANISTAN
PAKISTAN
CHINA
(TIBET)
NEPAL
BHUTAN
BANGLADESH
MYANMAR
SRI LANKA
JAMMU & KASHMIR
HIMACHAL PRADESH
PUNJAB
HARYANA
DELHI
New Delhi
UTTARAKHAND
UTTAR PRADESH
RAJASTHAN
SIKKIM
BIHAR
ARUNACHAL PRADESH
ASOM (ASSAM)
NAGALAND
MEGHALAYA
MANIPUR
TRIPURA
MIZORAM
JHARKHAND
WEST BENGAL
MADHYA PRADESH
GUJARAT
CHHATTISGARH
(ODISHA) ORISSA
DADRA & NAGAR HAVELI
MAHARASHTRA
TELANGANA
GOA
KARNATAKA
ANDHRA PRADESH
KERALA
TAMIL NADU
LAKSHADWEEP (INDIA)
ANDAMAN & NICOBAR ISLANDS (INDIA)
ARABIAN SEA
BAY OF BENGAL
INDIAN OCEAN
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LEGEND
International Boundary
State Boundary
Country Capital
Zone - II (Least Active)
Zone - III (Moderate)
Zone - IV (High)
Zone - V (Highest)
Map not to Scale
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D) THE DESIGN IS TO BE REPEATED LARGE NO. OF TIMES TO ENSURE ECONOMY IN INVESTING PRECAST MOULDS, PROCESS, CRANES ETC.

HOWEVER, SLOWLY THE SOLUTIONS ARE BEING WORKED OUT TO ULTIMATELY ADOPT PRECAST ELEMENTS IN MASS HOUSING PROJECT.

JAIN TEMPLE AT CHENNAI

USING BAMBOO IN PLACE OF STEEL

THUS BAMBOO CAN BE EFFECTIVELY USED AS REPLACEMENT OF REINFORCING STEEL TO SAVE ENERGY.

IN THE PROJECT OF JAIN TEMPLE, THE USE OF REINFORCING STEEL WAS NOT ALLOWED FROM RELIGIOUS CONSIDERATIONS. SO BAMBOO WAS USED IN PILE, PULE CAP, COLUMNS & BEAMS.

MORE WORK IS REQUIRED TO BE CARRIED OUT IN THIS FIELD.

CONCLUSION:

WHILE MAINTAINING STRUCTURAL SAFETY, IT IS ALSO ESSENTIAL TO INCORPORATE STRUCTURAL DESIGN & CONSTRUCTION ASPECTS IN THE DESIGN OF GREEN BUILDING, AS A VERY LARGE PERCENT OF ENERGY REQUIREMENT IS AFFECTED BY THE BASIC STRUCTURE OF THE BUILDING.

THANK YOU