PREFAB TECHNOLOGY FOR MASS HOUSING: SEISMIC SAFETY AND SUSTAINABLE ISSUES

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Vision 2022: India's housing need by 2022
India's commitment to inclusive, sustainable, and affordable development
1 crore annual urban population growth expected by 2050
11 crore houses will likely be required by 2022
70 per cent of the urban housing need is in the afforable segment
30 per cent of the housing need is concentrated in just two states

CONSTRUCTION SECTOR – INDIAN SCENARIO

Buildings

Housing
Offices
Hospitals
Factories

Labour Intensive

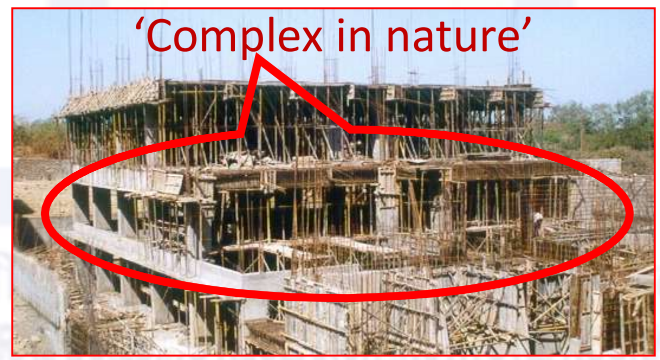
About 70% of market

- **Slow speed of construction**
- **High maintenance**
- **Skilled labour orientated**
- **Involvement of many trades**
- **High cost of land**
- **Complex construction process**

Civil Works

Infrastructure for
Water-supply
Transport (Road/Rail/Water/Air)
Irrigation
Power generation

Equipment & Machinery Intensive
Rest 30% of market

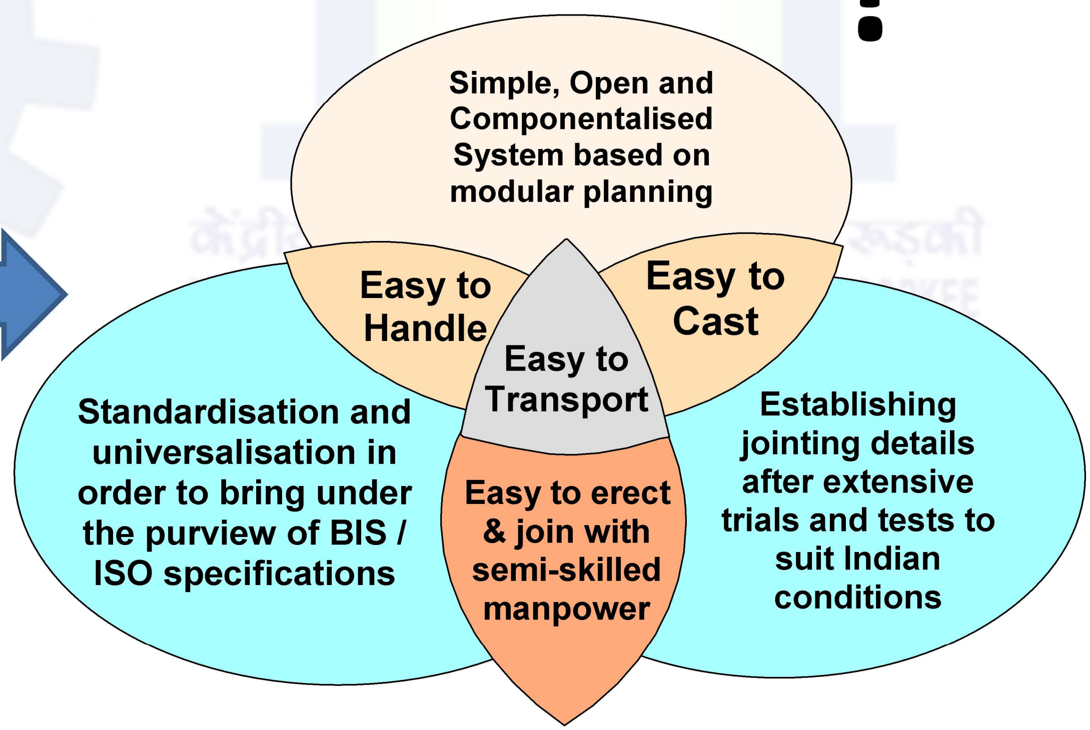


Cracks are not very uncommon

INDUSTRIALIZED CONSTRUCTION

- **Estimated a Huge requirement more than 200 Lacs units**
  - **Presently hardly @ 15% being constructed**
  - **Huge Backlog**
- **With this speed 10-12 Yrs. to fulfill present requirement only.**
- **What about requirement and the backlog in these 10-12 Years ?**

? **Certainly the supply is not commensurate with the demand** **?**



CSIR-CBRI's CONTRIBUTION TO PREFAB

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Semi-mechanized Production of Precast Building Components

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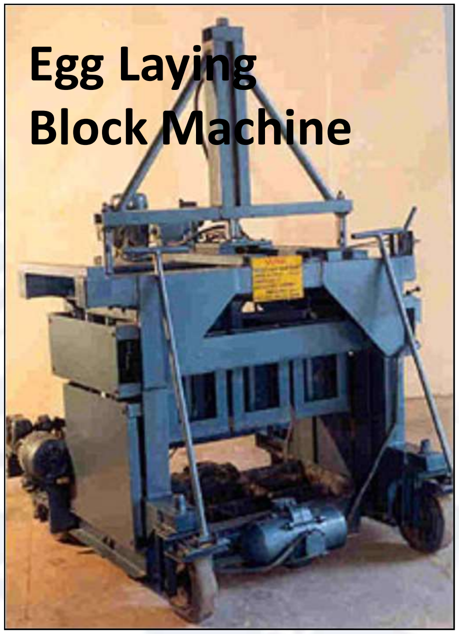
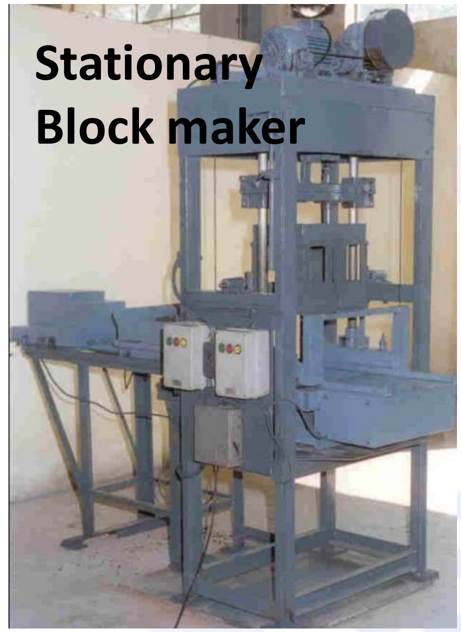
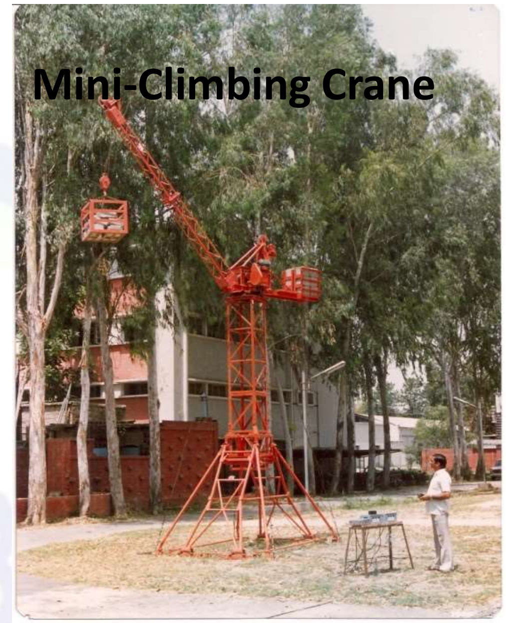
Mechanization





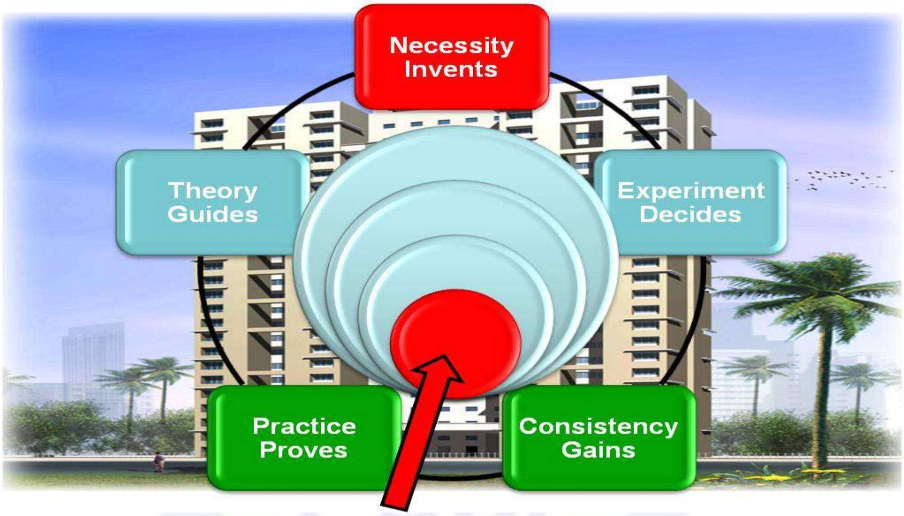


Building Components- From
Concrete Cored Unit

Hollow and Solid blocks
by Block Making Machine

CSIR-CBRI's CONTRIBUTION TO PREFAB

Seismic and Fire Resiliency Evaluation

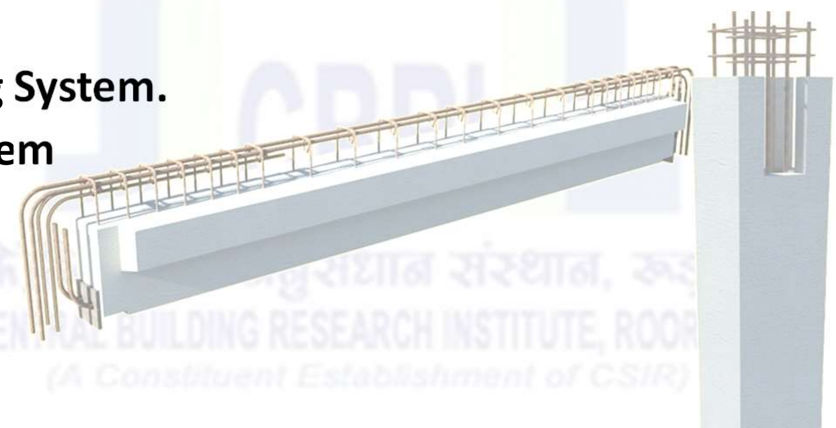


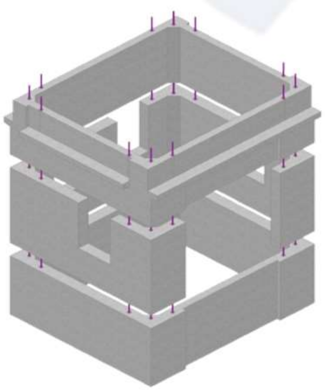
Full-Scale Test on Two Storied Prefab RC Building (3S Technology)

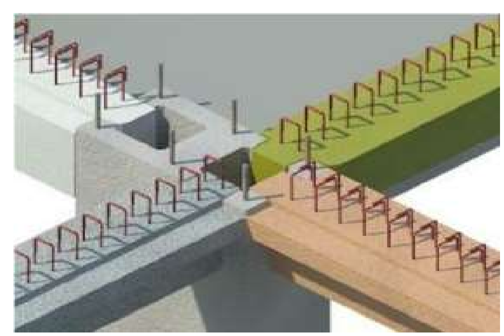
MASS HOUSING– INDIAN SCENARIO

Technologies

- **Conventional building system**
- **Cast *in-situ* formwork systems:** **with steel / aluminum/ plastic formwork**
- **Industrialized Prefabricated Concrete Systems:**
  - **3-S System using Precast Beams, Columns and Cellular Light Weight Concrete Slabs & Walls, Precast Slabs (Filigree), Precast Wall Panels**
  - **Expanded Polystyrene Core Panel System / Advanced Building System (EMMEDUE)**
  - **Factory Made Fast Track Modular Building System.**
  - **Glass Fibre Reinforced Panel Building System**
  - **Speed Floor System.**
  - **Light Guage Steel Framed Structures**







MASS HOUSING– INDIAN SCENARIO

Limitations in Indian Prefab Technologies

Sr. No.	Technology	Limitations
1	Monolithic Concrete Construction System using Plastic -Aluminium Formwork.	• Sizeable time required for initiation of work as the formwork are designed and manufactured. • Because of small sizes of form / shuttering panels, finishing **lines are seen on the concrete surface**. • Formwork requires number of spacers, wall ties etc. , which produce problems such as **seepage, leakage** during monsoon. • Accelerated curing is required. • **More logistic** is required for transportation of reinforcement, concrete. • **Special equipments** are required for pouring of concrete into forms. • **Limitations on reuse of formwork** due to denting in handling the forms. • **Wastage of concrete** while pouring. • Requires **close quality monitoring & checks due to placement** of steel reinforcement and concrete at site.
2	Monolithic Concrete Construction System using Aluminium Formwork.	

MASS HOUSING– INDIAN SCENARIO

Sr. No.	Technology	Limitations
3	Expanded Polystyrene Core Panel System / Advanced Building System (EMMEDUE)	• Lack of aesthetic special architectural features • Acceptability issue due to structural steel frame work.
4	Factory Made Fast Track Modular Building System.	
5	Glass Fibre Reinforced Panel Building System	Suitable for small & low rise structures only.
6	Speed Floor System.	Suitable for small & low rise structures only.
7	Light Gauge Steel Framed Structures	Suitable for small & low rise structures only.

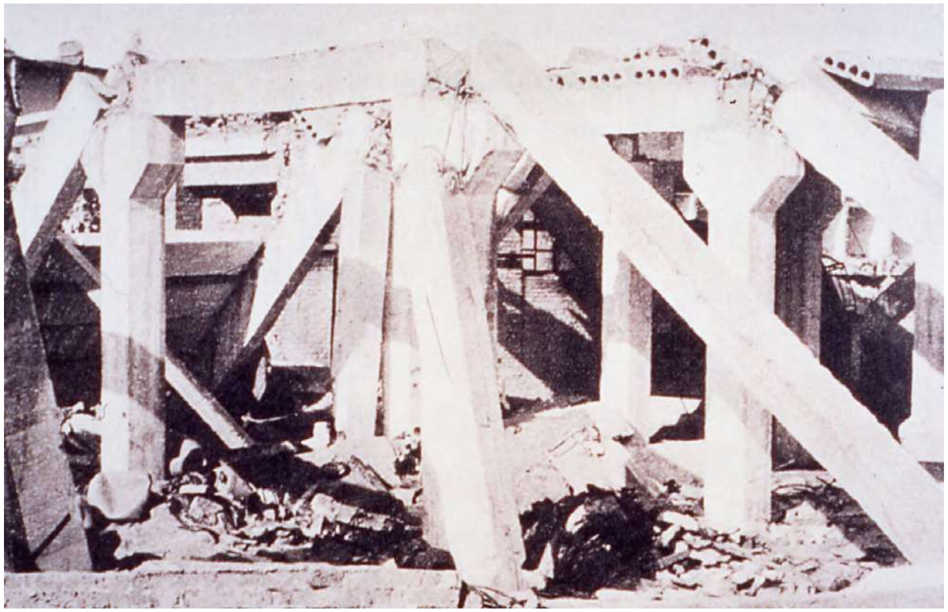
Tangshan, China - 1976

Leninkan, Armenia - 1988

The observed failures have been mainly due to brittle behaviour of poor connection details between the precast elements, poor detailing of the elements and poor design concepts. As a result the use of precast concrete was shunned in some countries in seismic zones for many years.

LESSONS FROM PREVIOUS EARTHQUAKE

Many precast concrete frame structures collapsed during the 1988 Armenian earthquake. These structures were typically nine storeys in height and contained hollow-core floor slabs. Some of the structures had some walls in one direction but these walls typically contained large openings. The beam-column connections were made by welding the beam bars to steel angles protruding from the precast columns. The floor diaphragms were poorly connected to the frame elements. Column splices were made by welding the vertical column bars.



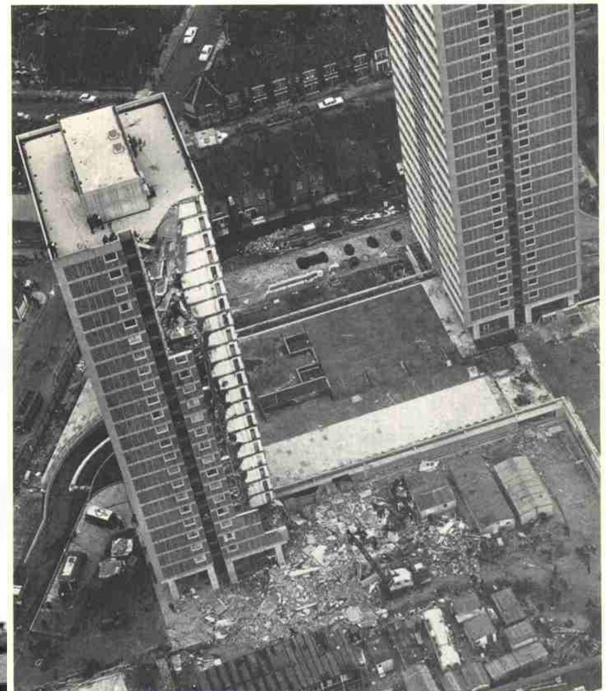

LESSONS FROM PREVIOUS EARTHQUAKE

A precast concrete column of the California State University 3-Storey parking structure that failed during the 1994 Northridge earthquake. This structure had exterior site-cast frames that were designed and detailed to be ductile.

The main interior girders in the N-S direction are precast pretensioned elements supported by corbels on the exterior cast-in-place columns and on the interior columns. A cast-in-place post tensioned slab spans between the beams in the E-W direction with the post-tensioning anchored at the exterior frames. The interior columns were designed to be gravity-load columns only with the lateral loads to be taken by the exterior frames. The mix of a very ductile system with the poorly detailed gravity-load columns interconnected by a flexible diaphragm led to brittle failures of several interior columns.

Northridge earthquake **- 1994**

LESSONS FROM PREVIOUS EARTHQUAKE

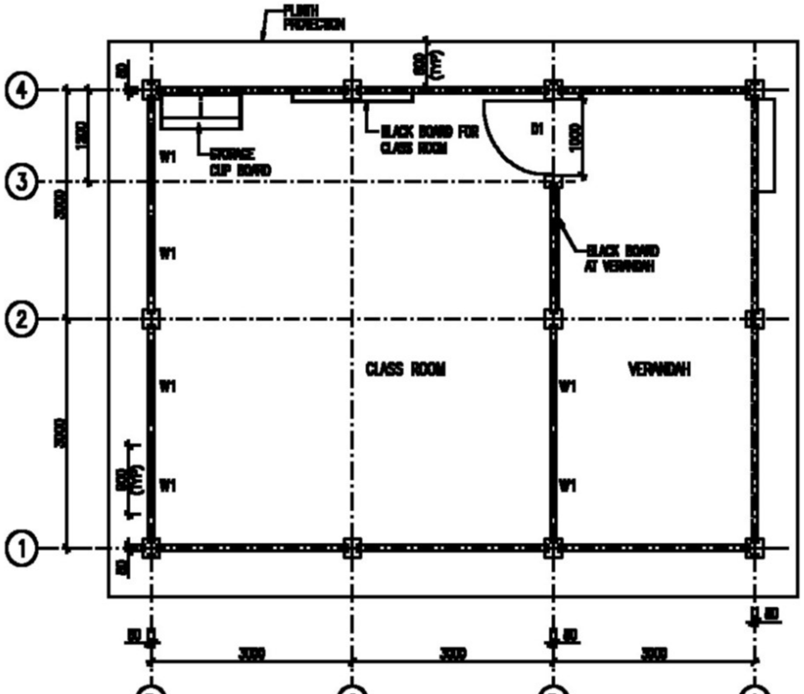


Ronan Point, London - 1968

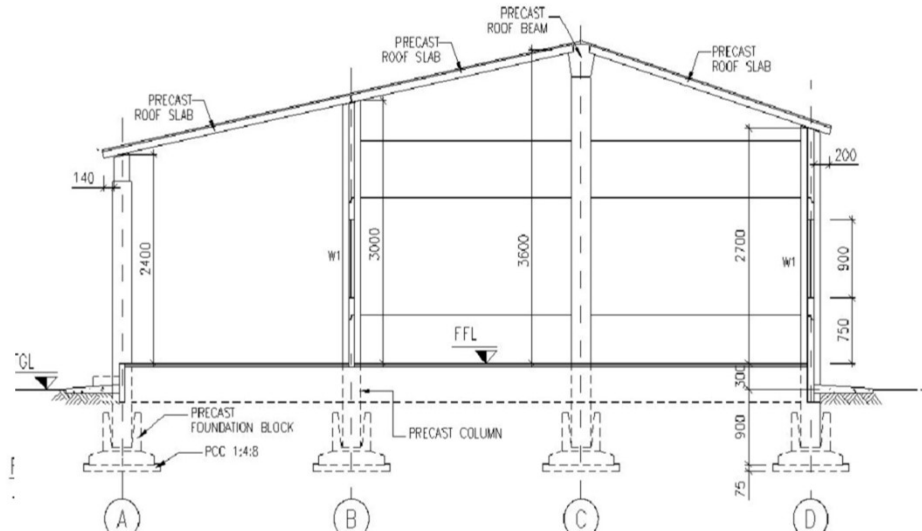
LESSONS FROM PREVIOUS FAILURES

Ronan Point was a 200 ft high block of flats.
Initially developed in Denmark in 1948 it featured external and internal walls and floors formed by large panels, approximately 150-175mm thick, of steel reinforced precast concrete.
The external wall panels relied mainly on friction to hold them in place.
A gas explosion occurred at 05.45 on Thursday 16 May 1968 in a one-bedroom flat on the south-east corner of the 18th floor of the block. Four people lost their lives from multiple crushing injuries in the ensuing collapse.

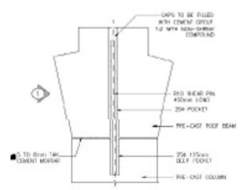
LESSONS FROM PREVIOUS EARTHQUAKE

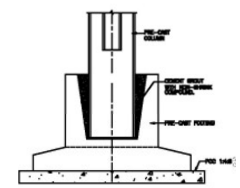


LAYOUT PLAN

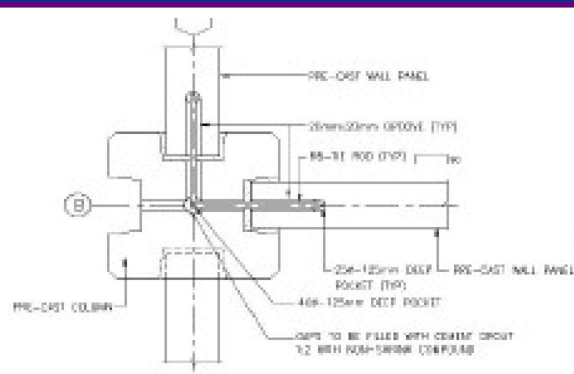


SECTION

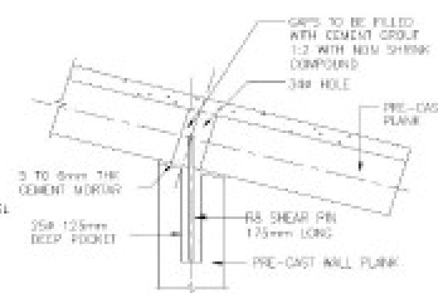

COLUMN – ROOF BEAM CONNECTION


TYP. FOOTING TO COLUMN CONNECTION

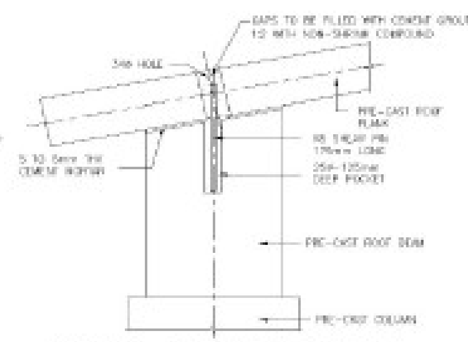
LESSONS FROM PREVIOUS EARTHQUAKE – GUJRAT SCHOOLS



WALL PLANK – COLUMN CONNECTION DETAIL



ALL – ROOF PLANK CONNECTION



ROOF BEAM – ROOF PLANKS CONNECTION

Type A – Major damage to structure
Type B – Slipping of roof planks
Type C – Minor dislocation of roof planks
Type D – Minor opening of grouted joints

LESSONS FROM PREVIOUS EARTHQUAKE – GUJARAT SCHOOLS

Almost all building rooms suffered damage, and about half of them experienced severe damage of Type A and B. It is clear from observed damage patterns that the weakest links in the precast school buildings were the connections between the structural elements. Roof planks resting on the beam slipped, indicating that the bearing area was inadequate and no positive anchorage was provided. Because of the poor connections, the provided roof slab system did not act as one unit to develop necessary diaphragm action, and the frames in the building system acted mostly independently.

Columns with isolated footings behaved as if they were hinged at the bottom and as a result, the building frames were subjected to excessive lateral deflection. Moreover, the redistribution of the forces was not possible because of the lack of redundancy in the building system. The precast system could not perform satisfactorily because the elements were not tied together.

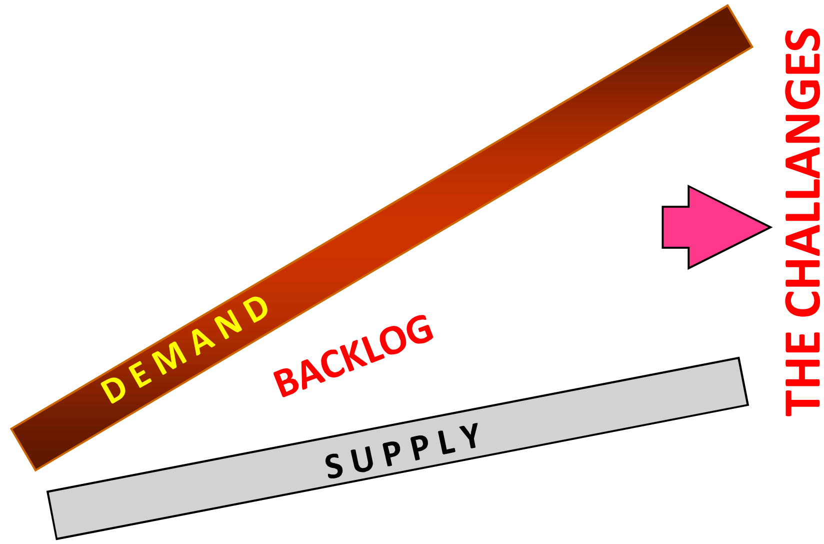
The Paramount Tower - 39 story moment frame
San Francisco, California

100 Washigntonn Square, Minneapolis, Minnesota, Canada

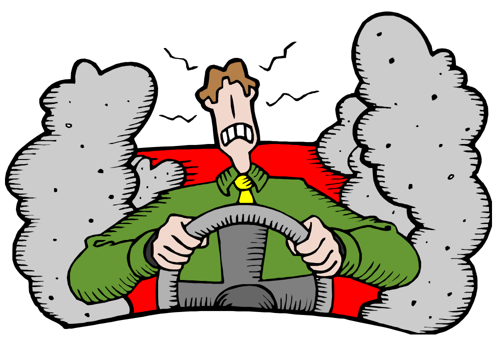
INSPIRATION FROM STANDING STRUCTURES

A 22 storey apartment building in Townsville

- Slow speed of construction
- High maintenance
- Skilled labour orientated
- Involvement of many trades
- High cost of land
- Usable area vs. Built-up area
- Involving lots of co-ordination between Architect, Structural Engineer, Constructer and other trades
- Complex construction process



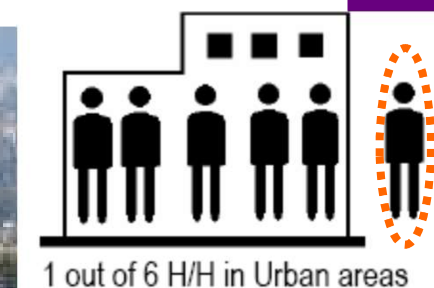
BUILDING CONSTRUCTION SCENARIO IN INDIA

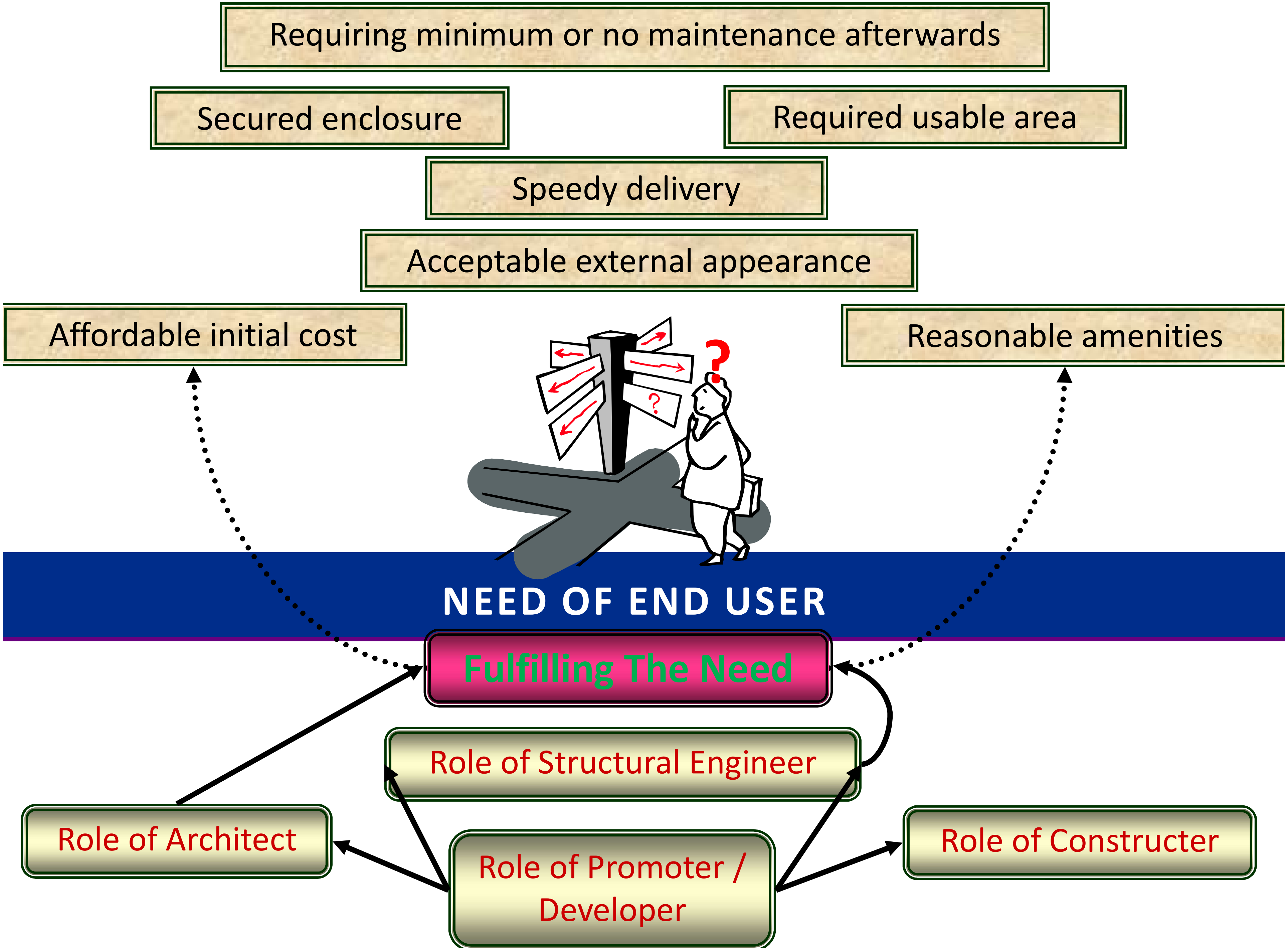


Architects and Engineers, as highly respected designers of the infrastructure, are in driving seat and in a unique position to influence such developments to be SUSTAINABLE, thereby resulting into 'QUALITY DELIVERABLES'.

70 Years since Independence

HAVING A SAFE SHELTER TO ALL IS FAR FROM REALITY!!!




Requiring minimum or no maintenance afterwards
Secured enclosure
Required usable area
Speedy delivery
Acceptable external appearance
Affordable initial cost
Reasonable amenities
NEED OF END USER
Fulfilling The Need
Role of Structural Engineer
Role of Architect
Role of Promoter / Developer
Role of Constructer

To choose appropriate Construction System which will fulfill the desired needs, such as…

- **Highest quality of construction resulting into 'SAFE' structures**
- **Giving maximum usable area within specified built-up area**
- **Requiring minimum input resources for the construction i.e. materials as well as manpower**
- **Extracting 'Maxima' output with 'Minima' inputs**
- **Early recruals of the investment**
- **Minimum maintenance**

NEED OF TIME – ASSURED TIMELY DELIVERY OF QUALITY BUILDINGS

To develop, promote and maintain the scientific temper for the sprit of innovation.

The technocrats require to take initiative in adopting sustainable construction techniques for the benefit of all and fulfill our prime duty for speedy creation of the structures requiring minimum resources standing for decades.

PRICE PROCUREMENT VS. VALUE PROCUREMENT

3 simple questions

? What ? → Strength & Durability

?? Why ? → Safety & Sustainability

??? When ? → Shortest possible time

3 simple answers

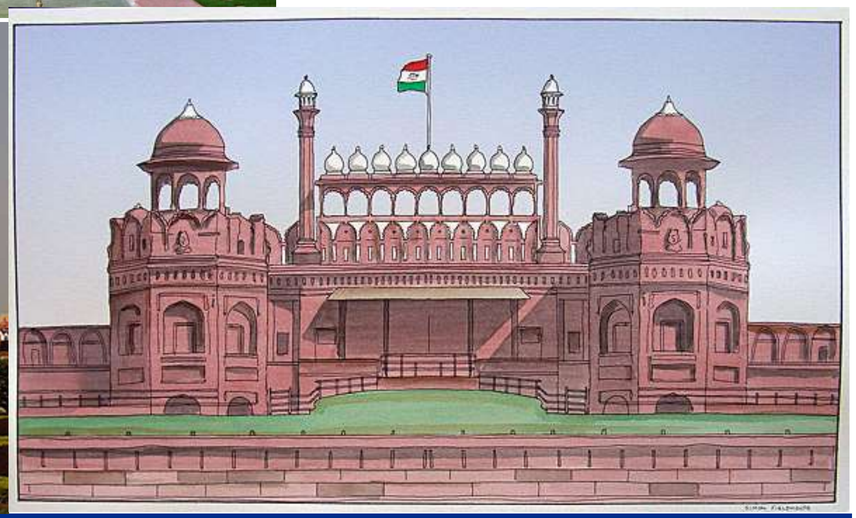
- Strength & Durability
- Safety & Sustainability
- Shortest possible time

Pre-requisites

- ✓ Judicial use of construction materials
- ✓ Reduction in wastage of materials
- ✓ Reducing emissions during the production of construction materials
- ✓ Using more durable materials
- ✓ Use of energy efficient building materials
- ✓ Use of products that contribute to a safe, healthy built environment
- ✓ Use of materials which can be recycled
- ✓ Use of construction system minimizing air, water and noise pollution during construction
- ✓ Life cycle cost

India has great history and heritage!

Precast construction techniques are not new to us!



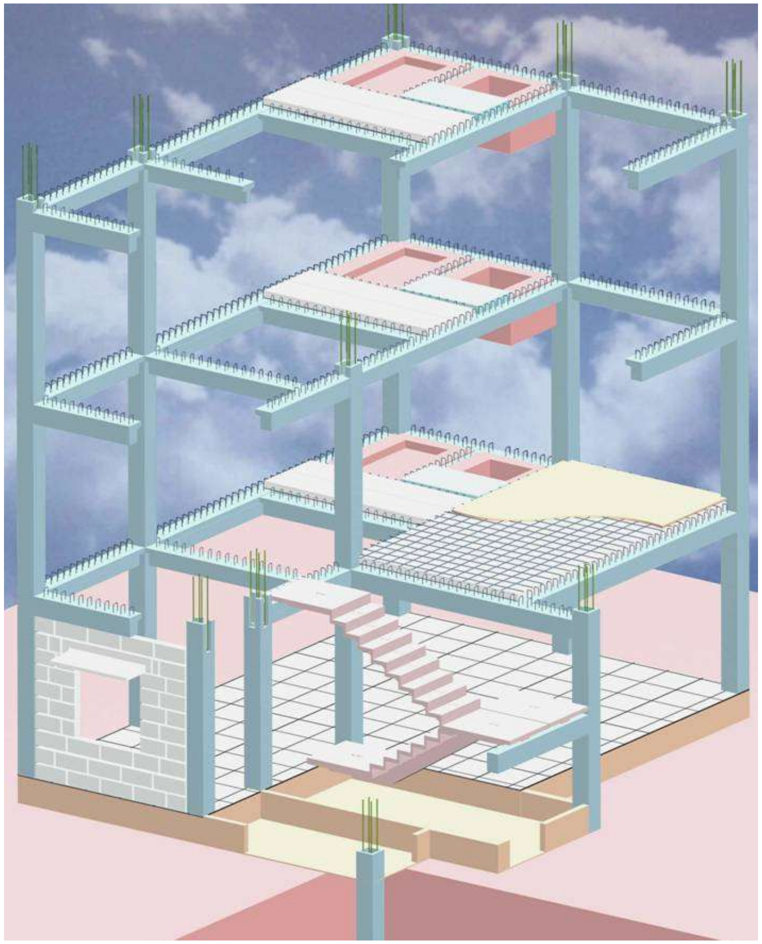
INSPIRATION

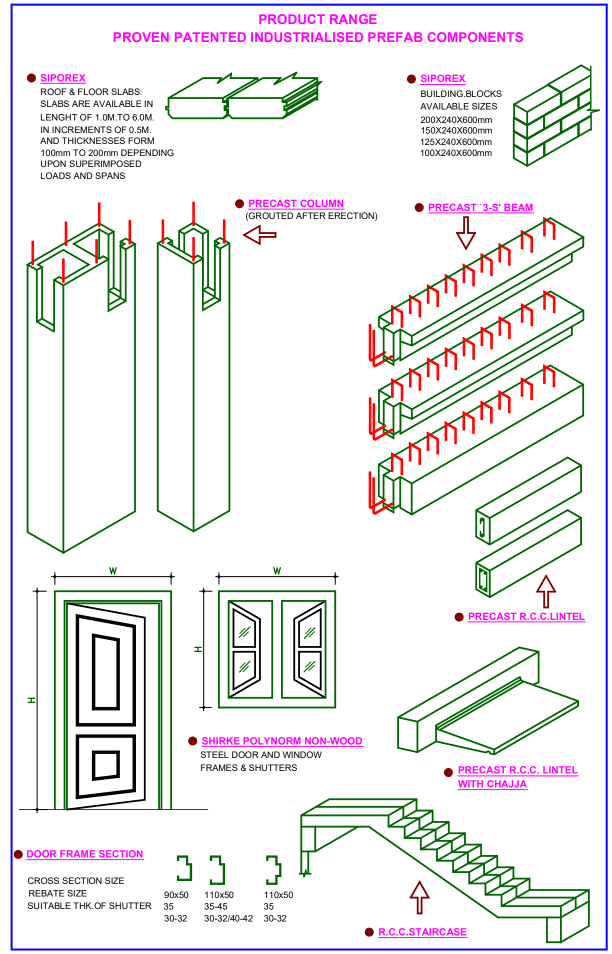
These monumental standing heritage structures are all precast !
– Not in concrete but in stone.

Not because concrete is not sustainable but due to it not invented at that time.

SUSTAINABLE TECHNOLOGY

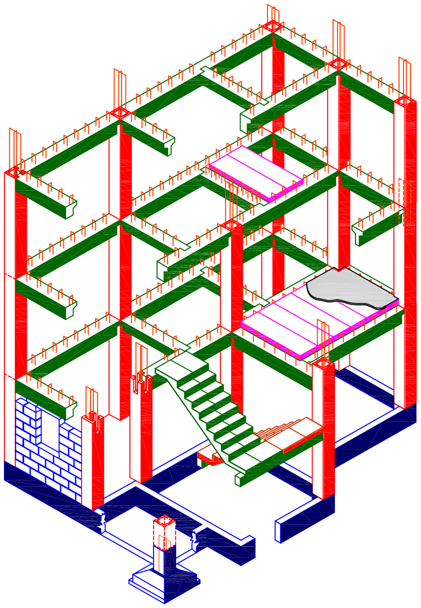
3-S PREFAB TECHNOLOGY





'3-S' is the brand name of Prefab Building Construction System fully developed and perfected by SHIRKE after years of strenuous Research and Development supplemented by extensive field trials.

As on date, buildings of G+4 to 25 storey admeasuring about 100 Million sft BUA have been constructed by this system.



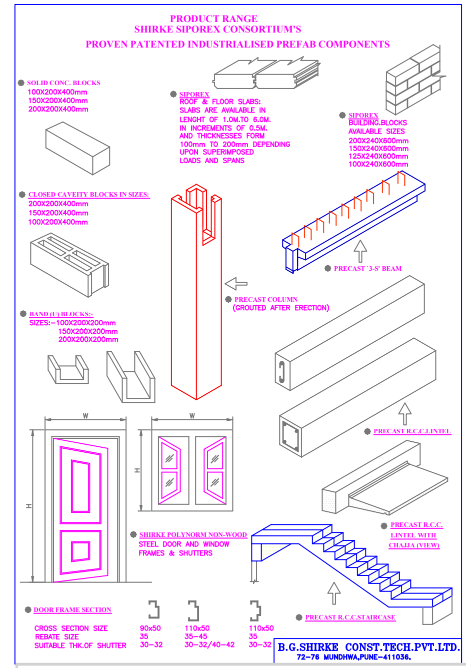
Time-tested, Eco-friendly and adaptable prefab technology in various climatic zones.

‘3-S’ SYSTEM

S-Strength S-Safety S-Speed

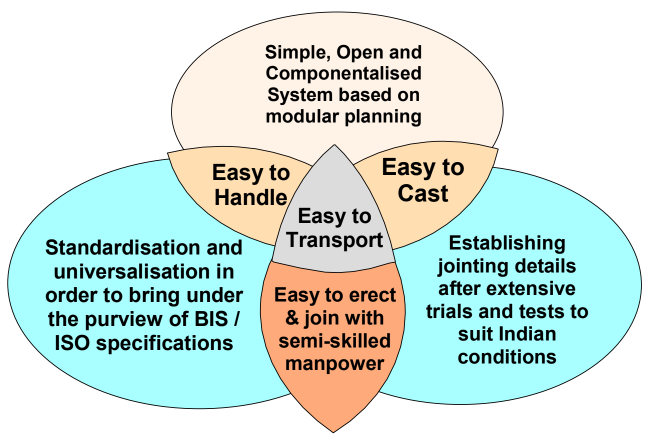
Structural components like Slabs, Columns and Beams are precast in casting yard having factory like condition.

‘3-S’ PREFAB components are erected, aligned and connected using SCC i.e. Self-Compacting Concrete of appropriate grade along with secured embedded reinforcement.



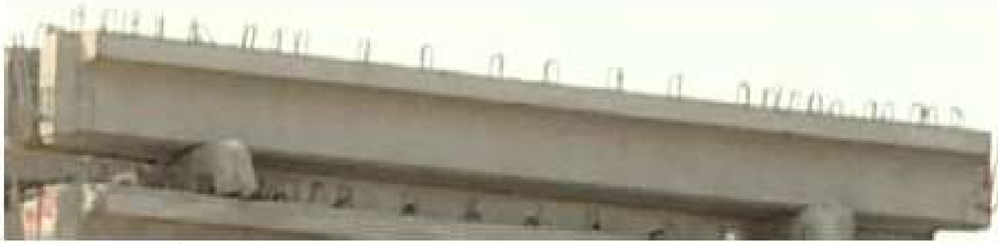
Being used since 1972 (More than 45 years)

TIME-TESTED & PROVEN ‘3-S’ PREFAB TECHNOLOGY



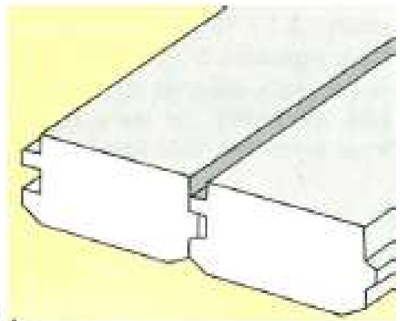
Prefab Components :

Column

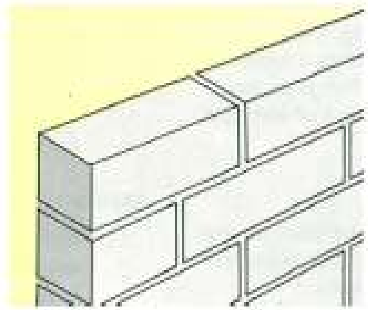


Beam

Slabs



Siporex Slabs



Siporex Blocks

Staircase

Wall

Loft

Lift wall

PREFAB COMPONENTS

Production facility : Rebar straightening, cutting, bending, caging, meshing, etc. by CNC machines



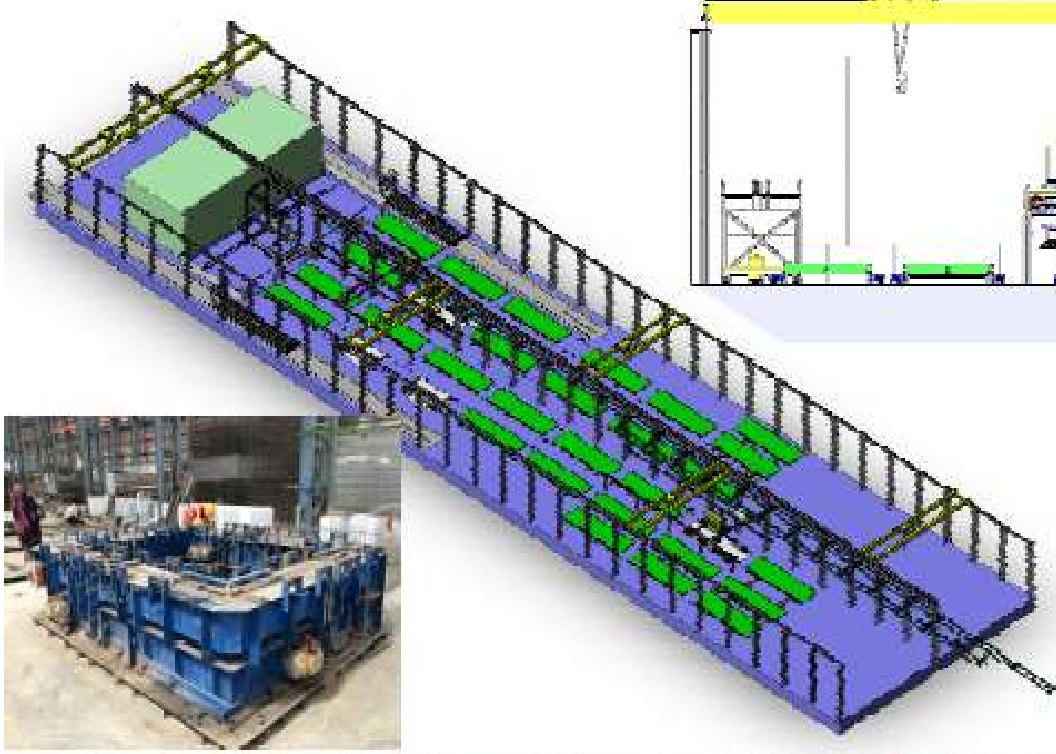


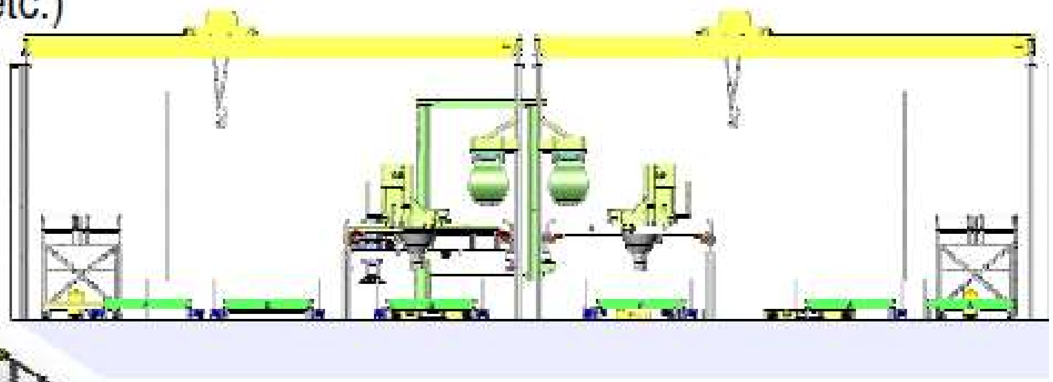




PRODUCTION FACILITY

Production facility : Carousel system for column, wall & slab production. Long line battery moulds for beam production & other precast components (lift wall, pardi, staircase, lintel, lintel with chajja, etc.)





Production facility (Autoclaved Cellular Concrete) : Siporex is a light weight autoclaved cellular concrete and is being used all over the world in more than 40 countries since 1930.

In Japan, Siporex is manufactured in about 11 factories amounting to a total production of about 3.3 million cum per year.

PRODUCTION FACILITY

Autoclaved Cellular Concrete

Dipping the reinforcement mats into phosphate solution and cleaning with wire brush.

Dipping into fresh water to wash away phosphate solution.

Dipping into chromate solution for passivity.

Dipping into Anti Corrosive Mix (i.e. Rubber Latex + Casein + Cement) for 1st coat and dried for 7 hours.

Dipping into Anti Corrosive Mix for 2nd coat and dried for 7 hours.

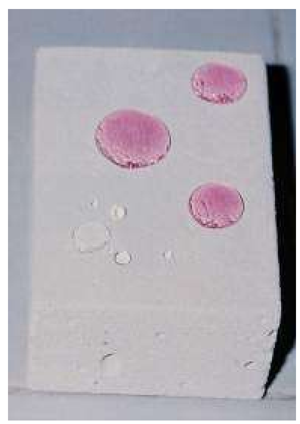
Dipping into Inertol-4253 for 3rd coat and dried for 7 hours. *Inertol and cement mix is prepared in proportion of 4:3, and consistency of the mix is controlled by addition of mineral terpentine or Xylene as thinner.*

Total thickness of these three coats is kept as 700 micron (minimum).

Pore size distribution in SIPOREX (Closed Cellular Structure)

Results of evaluation at Dept. of Geology, University of Pune during Sept. 1999

1. Cells are white in colour.
2. Cells are dominated with medium and finer size.
3. Cells larger than 2.5mm not observed.



Addition of Silicon in wet mass of SIPOREX and applying it on surface makes the product water repellent

Production facility : Component finishing, curing & handling equipment









QUALITY TESTS DURING PRODUCTION CYCLE

Quality tests during production cycle :

PRODUCTION FACILITY

Production facility :








Stack yards :

STACK YARDS

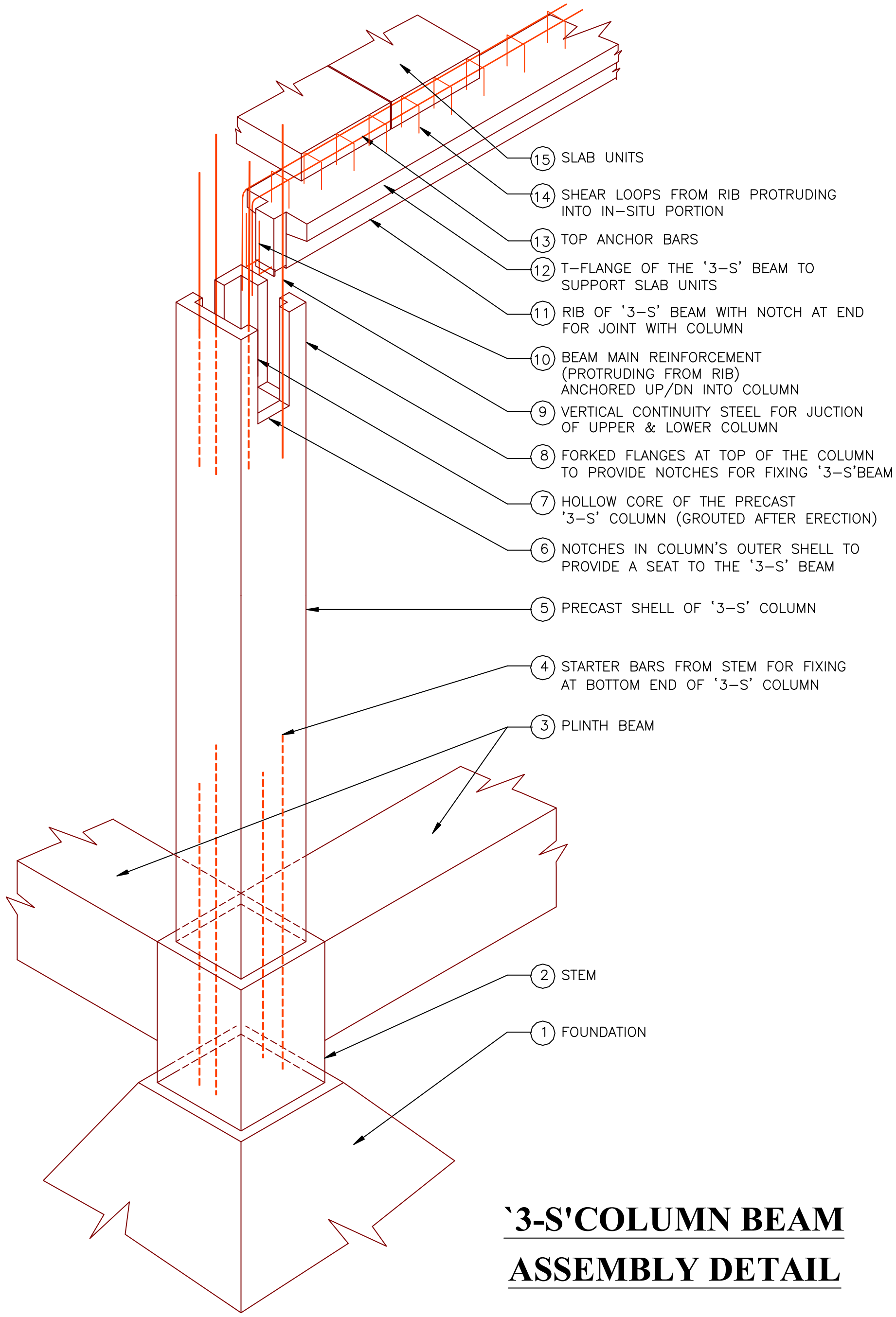
Erection : Components are erected, aligned and connected using <u>SCC</u> i.e. **Self-Compacting Concrete** of appropriate grade along with secured embedded reinforcement.

ERECTION

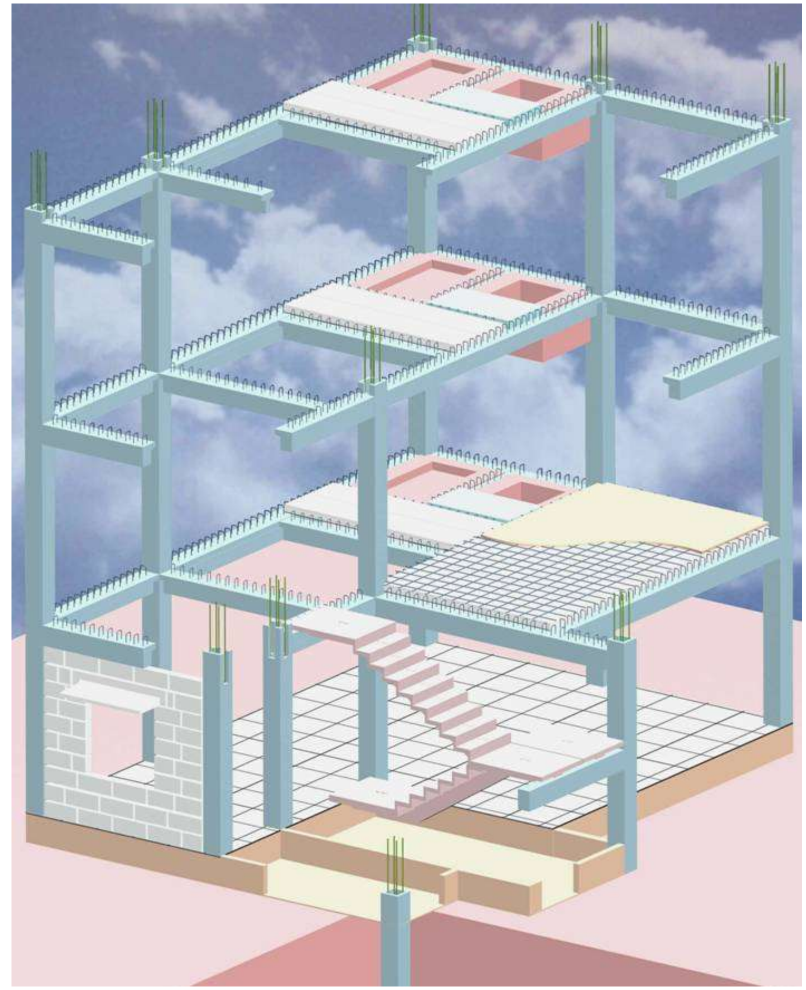
FACTORY ESTABLISHMENT AT VARIOUS LOCATIONS

Factory establishment at various locations : Maharashtra, Karnataka, Chennai & NCR Delhi

Connection details

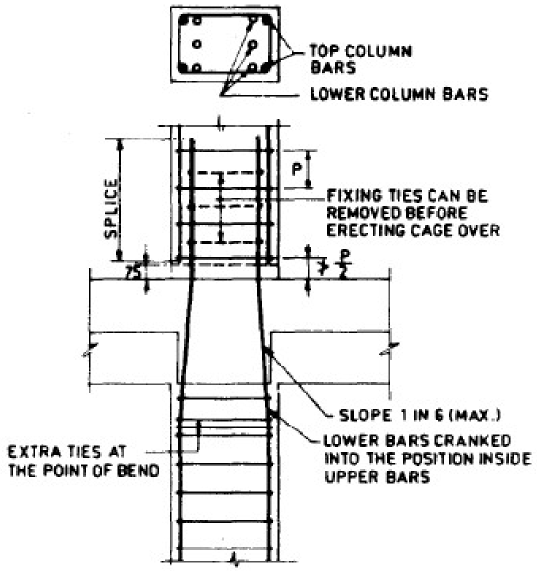


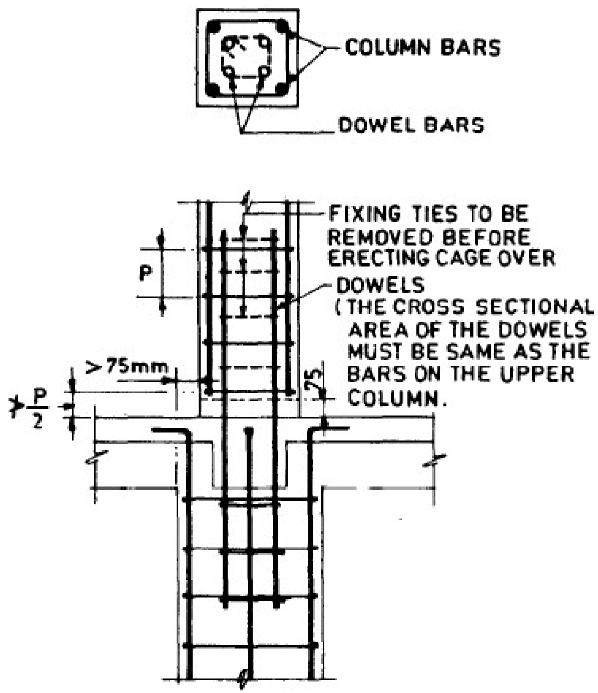
`3-S'COLUMN BEAM ASSEMBLY DETAIL



3-S PREFAB TECHNOLOGY

RECOMMENDED DETAILING SP: 34 AND NZS 3101-2006





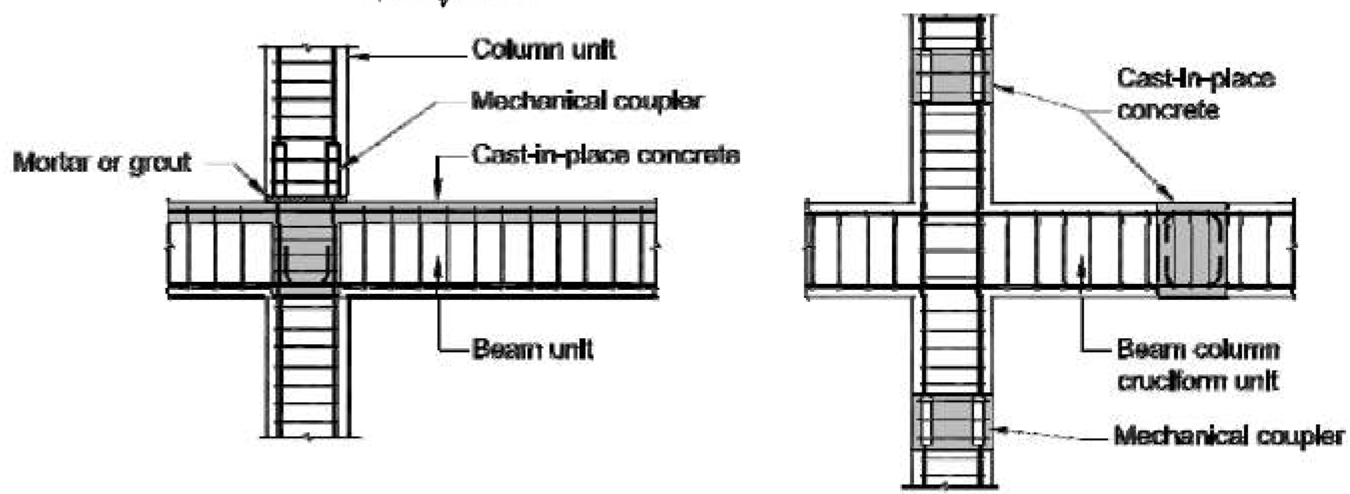
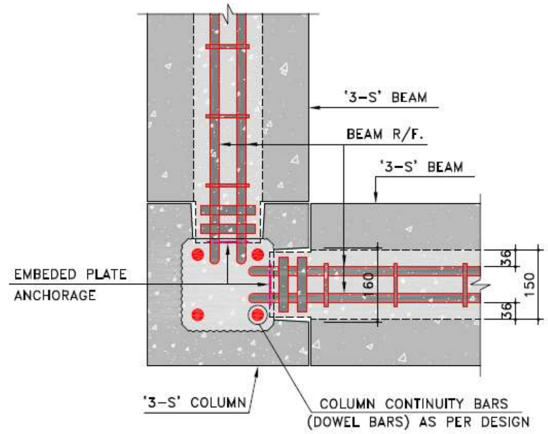
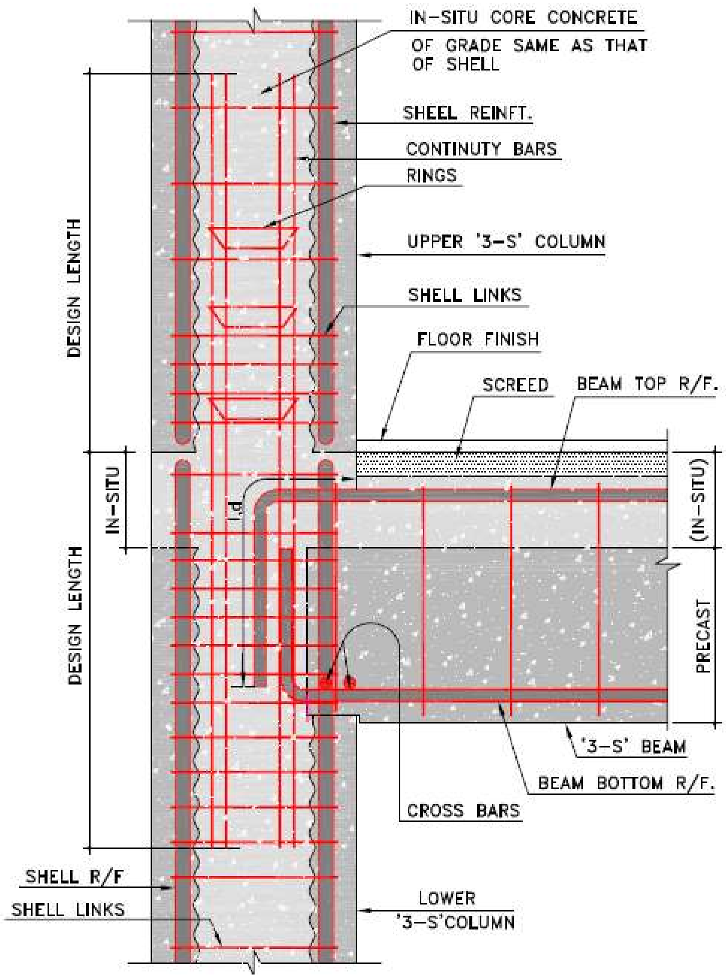
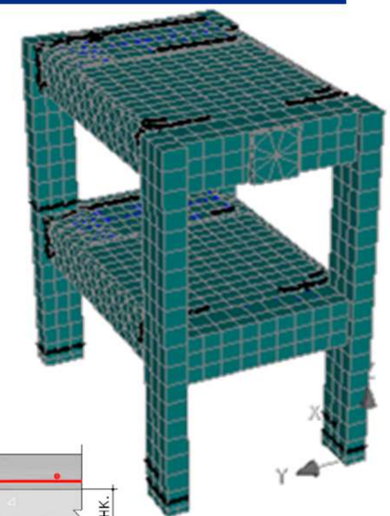


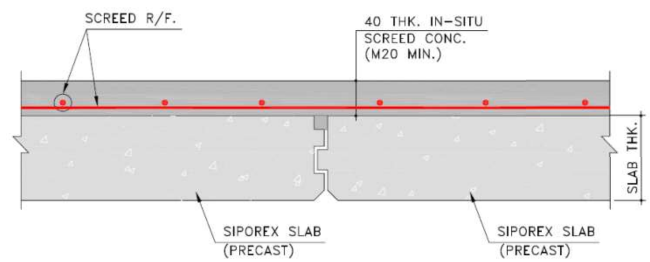
Figure CB.2 – Typical equivalent monolithic arrangements of precast reinforced concrete units and cast-in-place concrete [B.1, B.2]

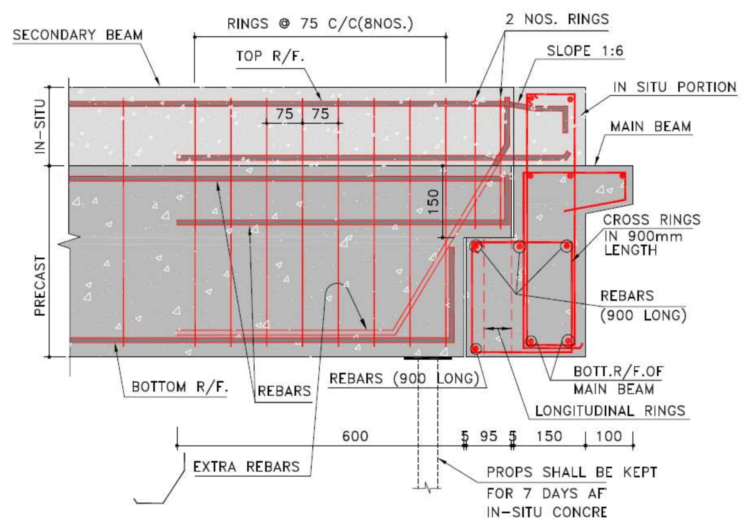
JOINT DETAILING PERFECTED AFTER TESTS





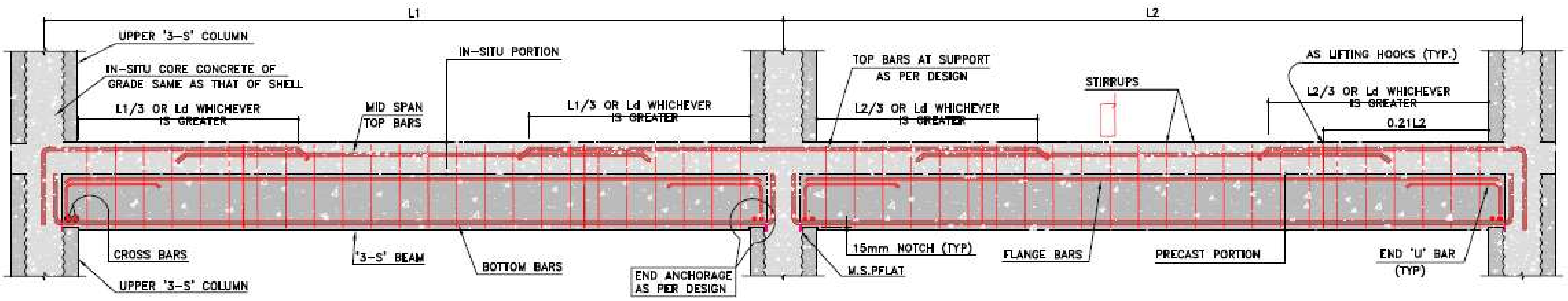




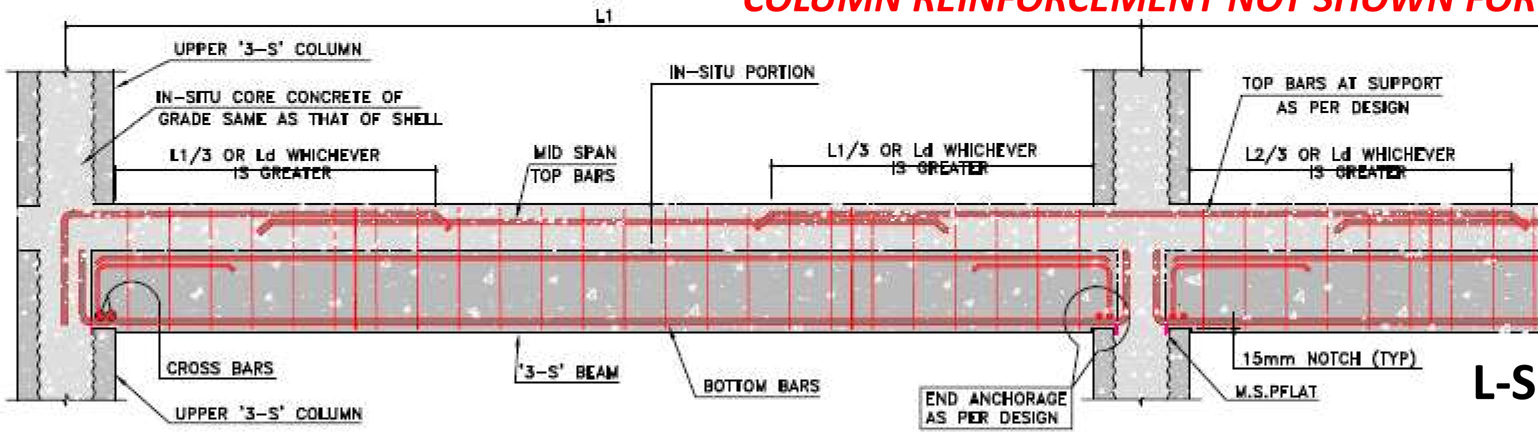


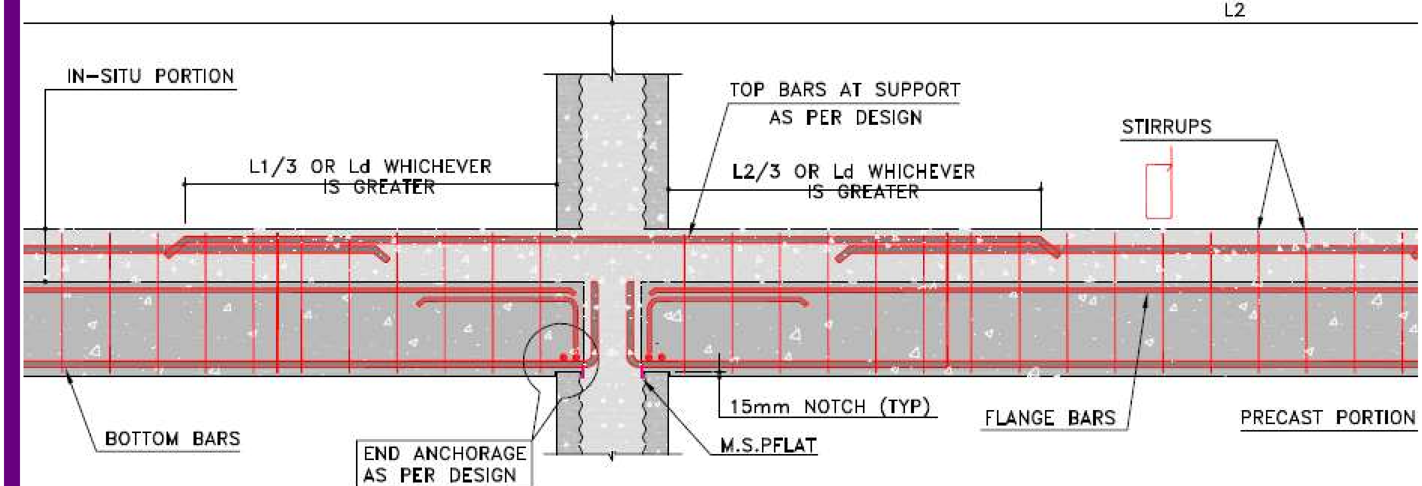
CONVENTIONAL CONCRETE STRUCTURE

JOINT DETAILING PERFECTED AFTER TESTS



COLUMN REINFORCEMENT NOT SHOWN FOR CLARITY

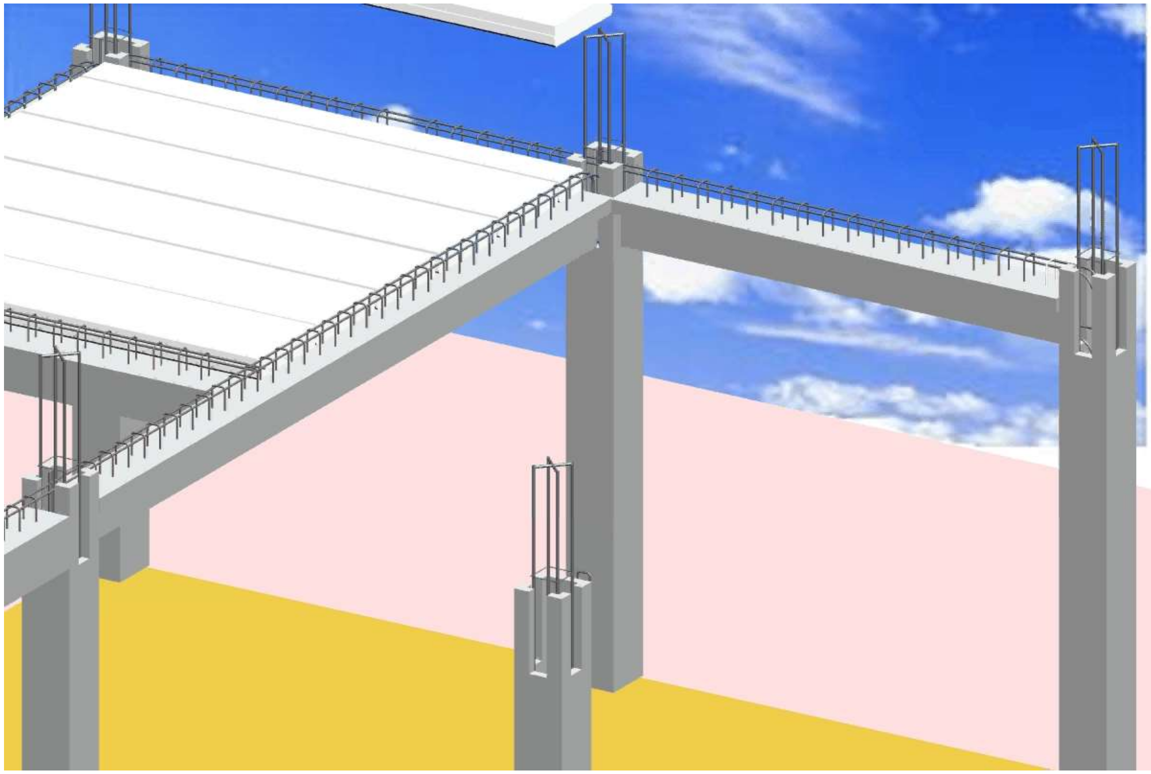




L-SECTION OF COLUMN-BEAM FRAME ASSEMBLY

CONVENTIONAL CONCRETE STRUCTURE

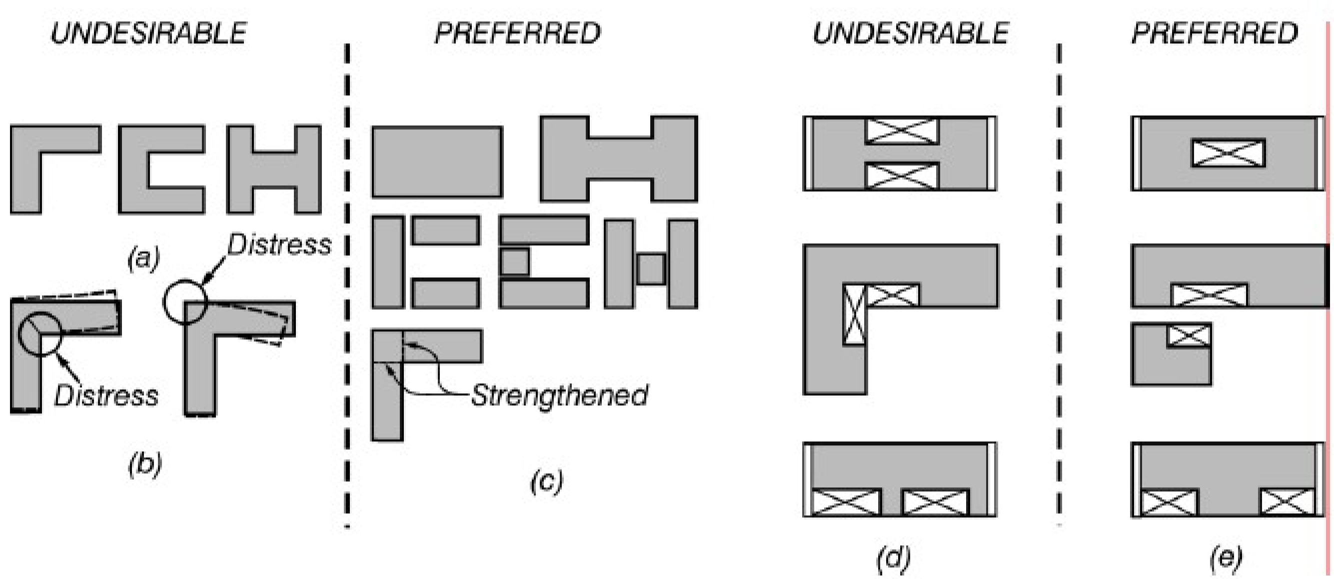
Construction details



Design details

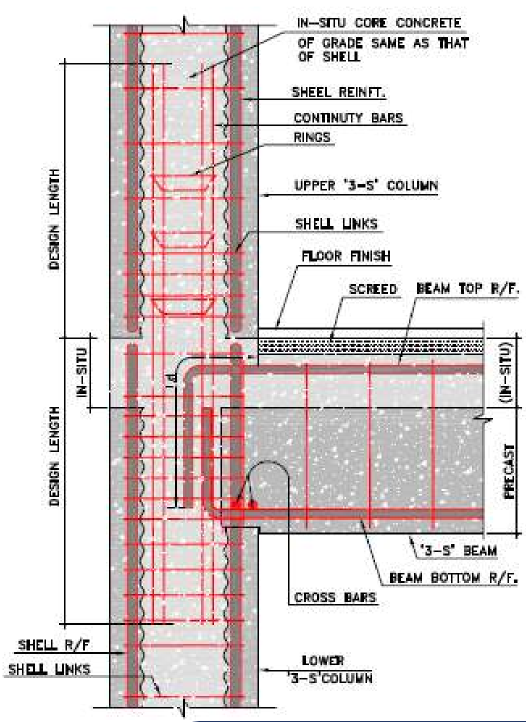
Horizontal loads are usually transmitted to moment resisting frames or to shear walls by the roof and floors acting as horizontal diaphragms. Diaphragm action can be described as the action of the floor/roof, acting as a deep beam, transmitting applied horizontal forces to the foundations.

A diaphragm floor/roof must be capable of sustaining shear forces and bending moments. The precast concrete floor is analysed by considering the slab to be a deep horizontal beam. The floor units must be tied and grouted together at the joints to ensure full plate action of the floor.



Building plan configurations – Undesirable Vs Preferred

PREFAB CONNECTIONS



PRECAST CONCRETE SYSTEM

Emulation of Monolithic Behavior

Jointed precast
(Relying on unique properties)

MOMENT FRAMES

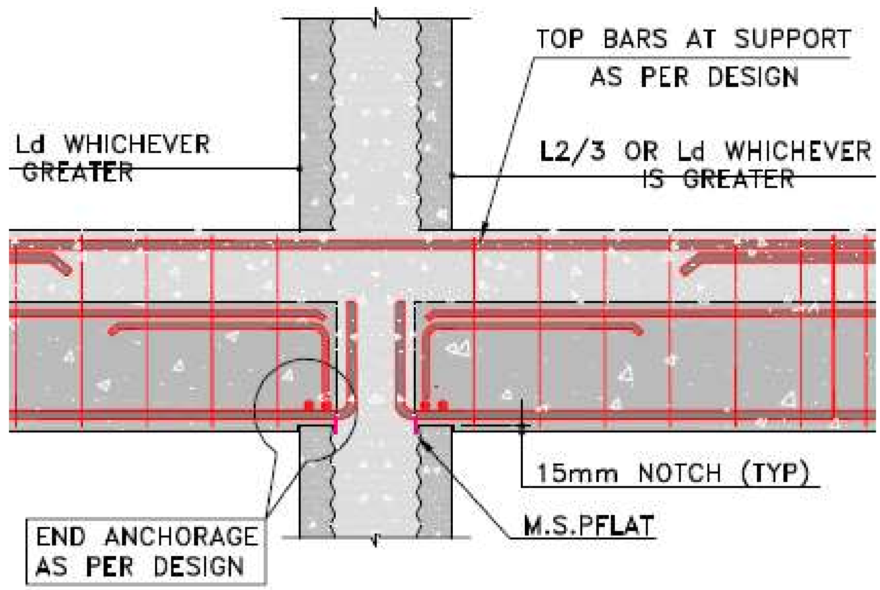
SHEAR WALLS

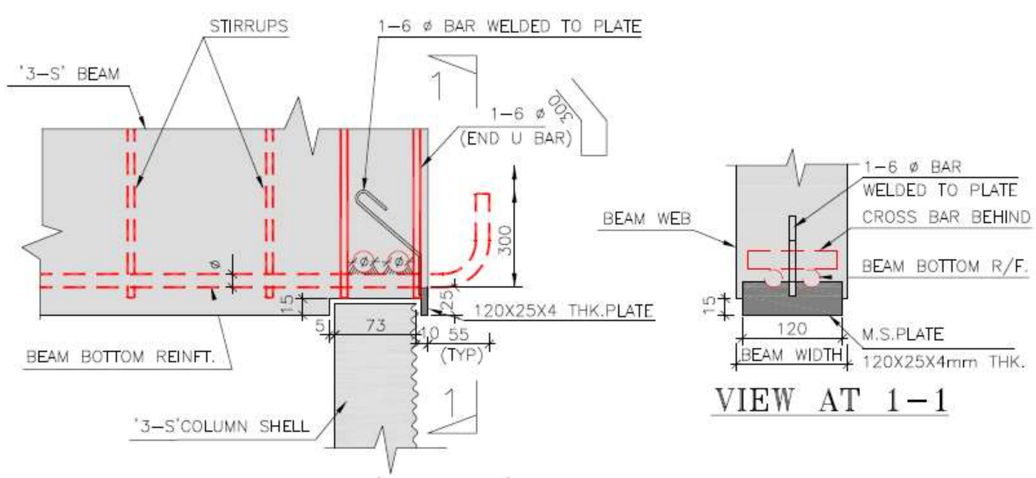
WET CONNECTIONS
(Ductile connections)

DRY CONNECTIONS
(Strong connections)

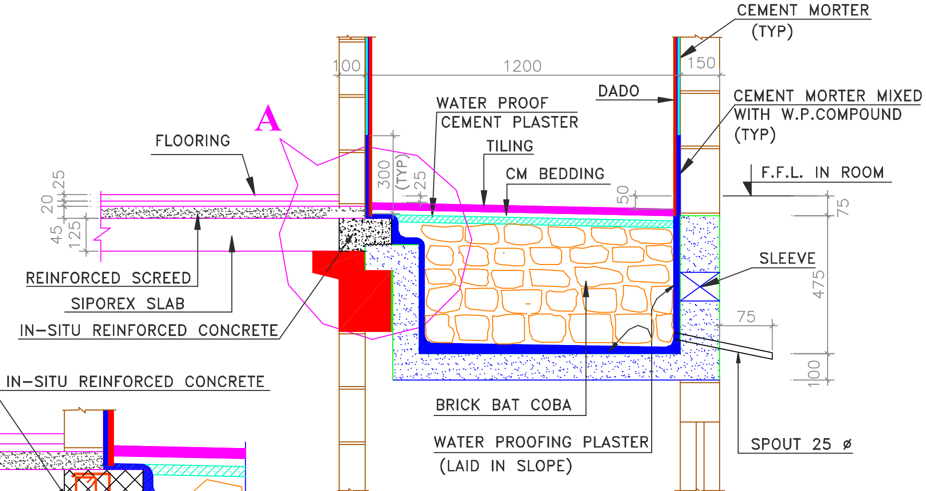
3-S PREFAB TECHNOLOGY

Construction details

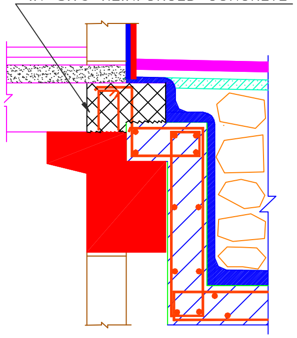




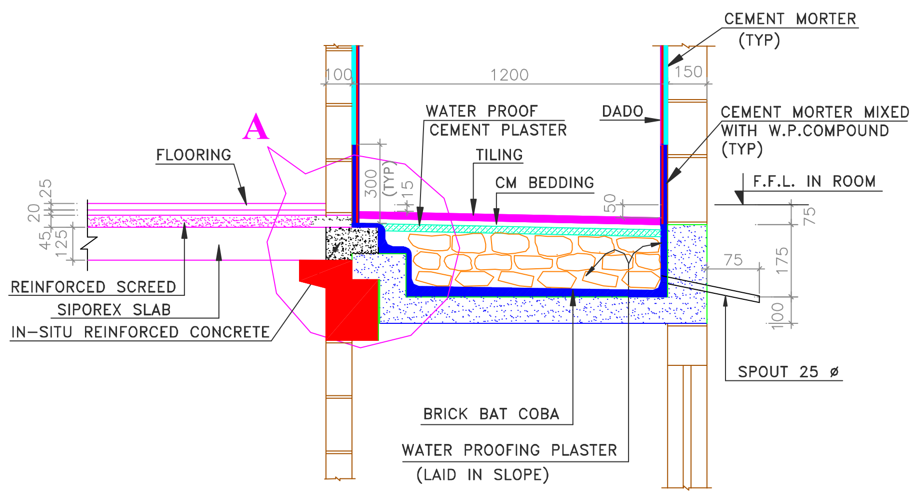
All the connections are through in-situ self-compacting concrete with appropriate reinforcement ensuring continuity.



TYP. W.C. SLAB DETAIL



DETAIL AT (A)



TYP. BATH SLAB DETAIL

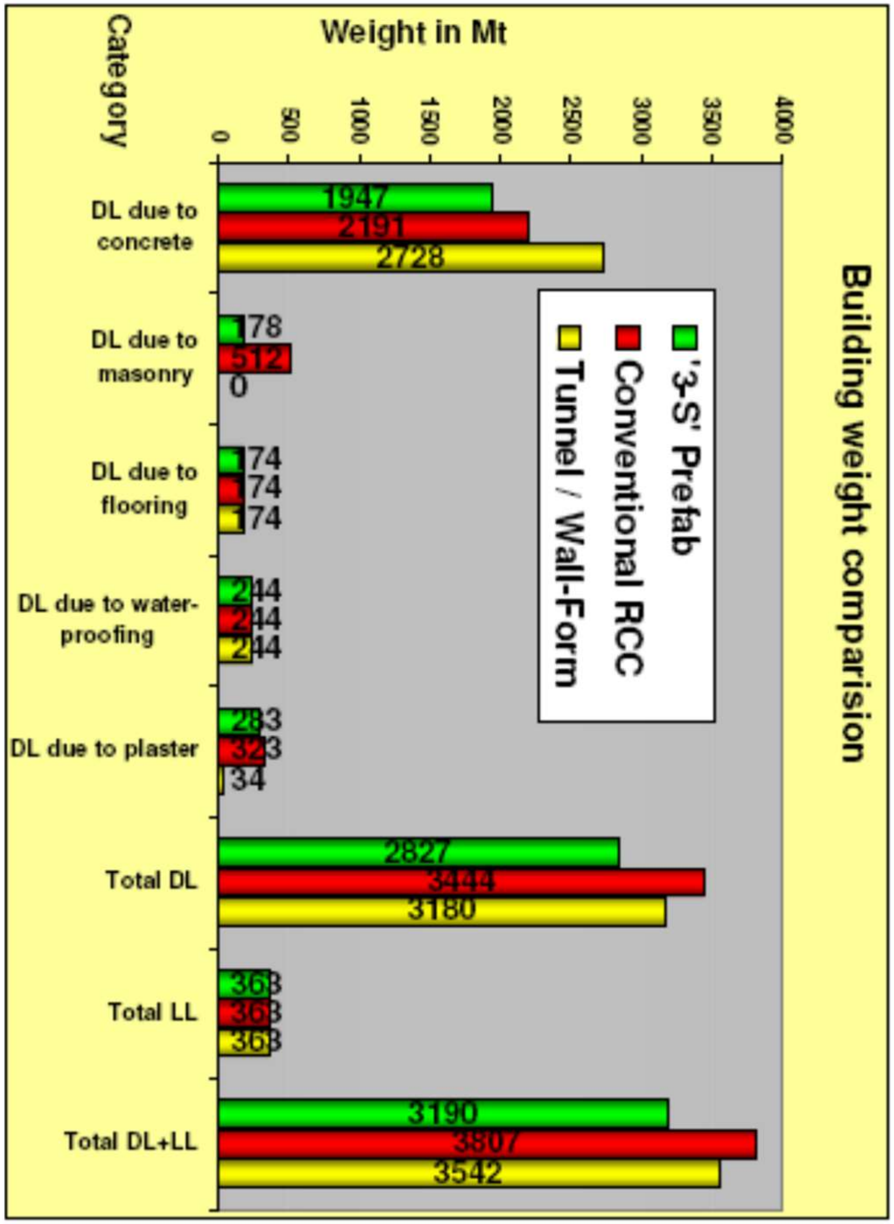
Construction details

Time-tested, Eco-friendly and adaptable prefab technology in various climatic zones.

All the connections are through in-situ self-compacting concrete with appropriate reinforcement ensuring continuity and composite action

Most suitable in Seismic Prone areas being Rigid Monolithic 'WET' jointing of precast RCC structural components i.e. using in-situ concrete.

SUITABILITY OF '3-S' PREFAB STRUCTURE IN SEISMIC PRONE AREAS



Concrete load is 65% less than that in conventional structures

Masonry load is 65% less than that in conventional structures

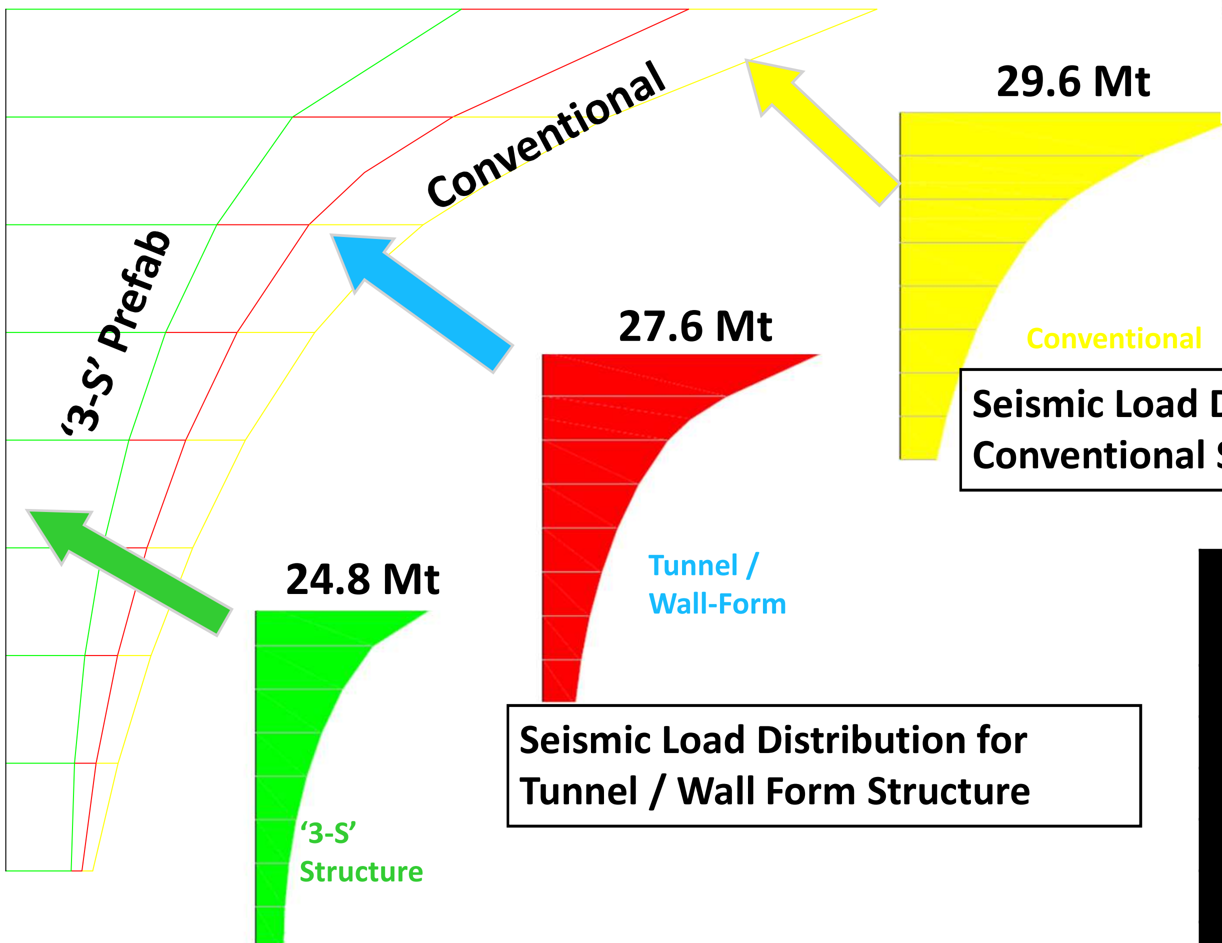
Flooring, Water-proofing and Plaster load is same as that in conventional structures

Dead load is 18% less than that in conventional structures

Total load of structure is 16.5% less than that in conventional structures and 10% less than that in Tunnel / Wall-Form Structures

SUITABILITY OF '3-S' PREFAB STRUCTURE IN SEISMIC PRONE AREAS

Values as determined for G+7 storey building plan



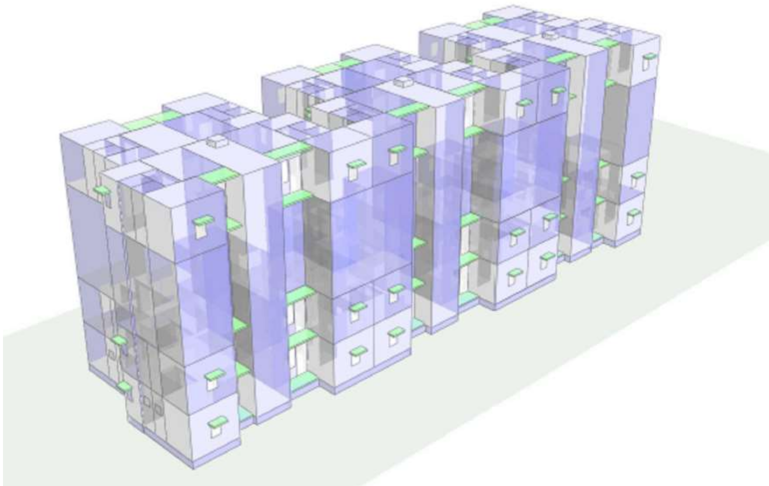
Seismic Load Distribution for Conventional Structure

Seismic Load Distribution for Tunnel / Wall Form Structure

Seismic Load Distribution for '3-S' Prefab Structure

Height	'3-S' Prefab	Conventional RCC	Tunnel / Wall-Form
23.68	24.8	29.6	27.6
20.72	19.0	22.7	21.1
17.76	14.0	16.7	15.5
14.80	9.7	11.6	10.8
11.84	6.2	7.4	6.9
8.88	3.5	4.2	3.9
5.92	1.6	1.9	1.7
2.96	0.4	0.5	0.4

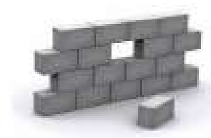
THERMAL PERFORMANCE STUDY OF '3-S' PREFAB STRUCTURE



Envelope Options for Study

Base Case

External Wall : 150mm AAC Block + Plaster (Internally & Externally)
Internal Wall : 100mm AAC Block + Plaster (Internally on both faces)
Slabs : 125mm AAC + 40mm RCC Screed topping

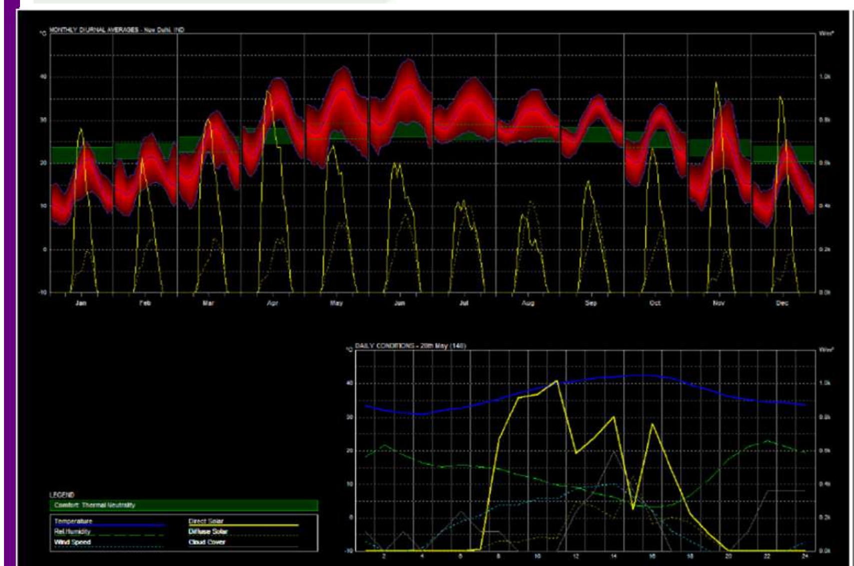


Option 1

External Wall : 150mm AAC Block + Plaster (Internally & Externally)
Internal Wall : 100mm AAC Block + Plaster (Internally on both faces)
Slabs : 90mm RCC + 40mm RCC Screed topping

Option 2

External Wall : 120mm RCC without plaster (Form finish)
Internal Wall 120mm RCC without plaster (Form finish)
Slabs : 100mm RCC



Winter
2nd January
Mean Min 5.6
Mean Max 25.1

Summer
29th May
Mean Min 18.7
Mean Max 44.3

Monsoon
25th July
Mean Min 37.2
Mean Max 24.2

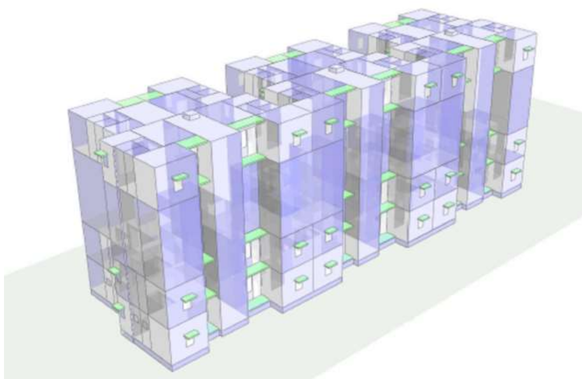
	External Wall	R-Value m^2 K/W			U-Value $1/\Sigma R$
		Envelope	Outside surface	Inside surface	
Base Case	150mm AAC	1.2438	0.04	0.13	0.71
Option 1	150mm AAC	1.2438	0.04	0.13	0.71
Option 2	120mm RCC	0.0857	0.04	0.13	3.91

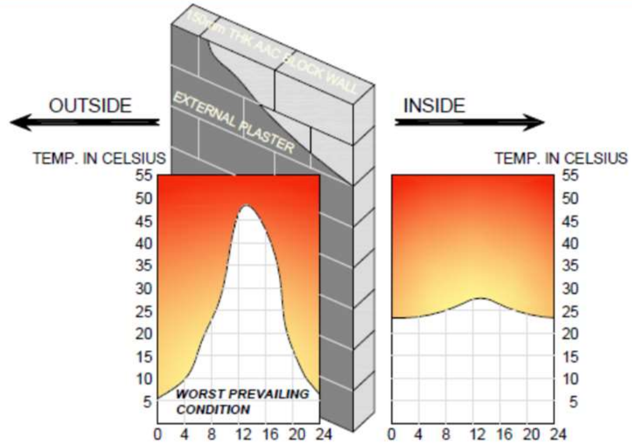
	Internal Wall	R-Value m^2 K/W			U-Value $1/\Sigma R$
		Envelope	Outside surface	Inside surface	
Base Case	100mm AAC	0.8542	0.13	0.13	0.90
Option 1	100mm AAC	0.8542	0.13	0.13	0.90
Option 2	120mm RCC	0.0857	0.13	0.13	2.89

	Slab	R-Value m^2 K/W			U-Value $1/\Sigma R$
		Envelope	Outside surface	Inside surface	
Base Case	125mm AAC + 40mm RCC	0.9089	0.04	0.13	0.93
Option 1	90mm RCC + 40mm RCC	0.1618	0.04	0.13	3.01
Option 2	100mm RCC	0.0885	0.04	0.13	3.87

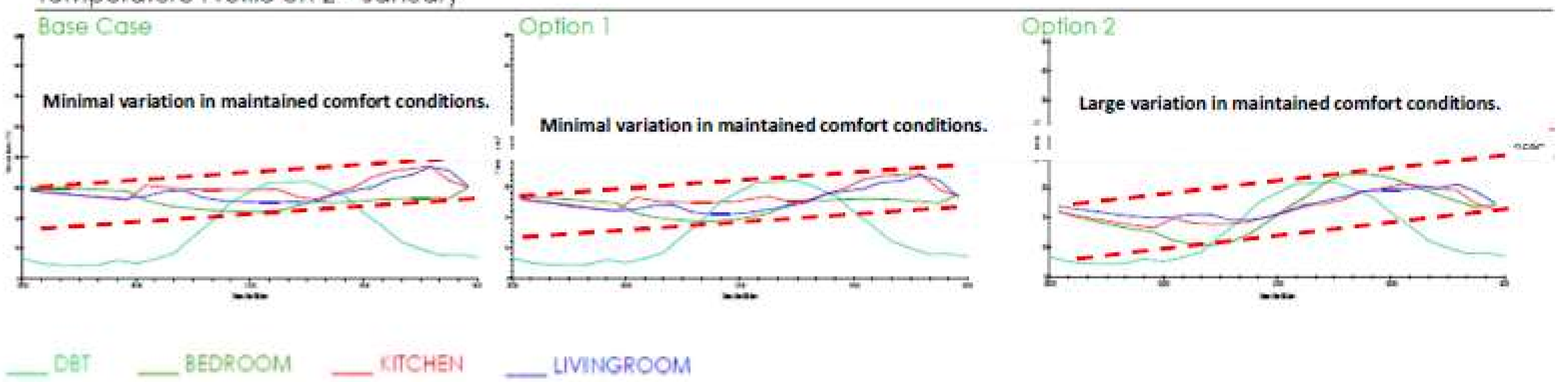
THERMAL PERFORMANCE STUDY OF '3-S' PREFAB STRUCTURE

Total Yearly Energy Consumption per Floor Area





Temperature Profile on 2nd January

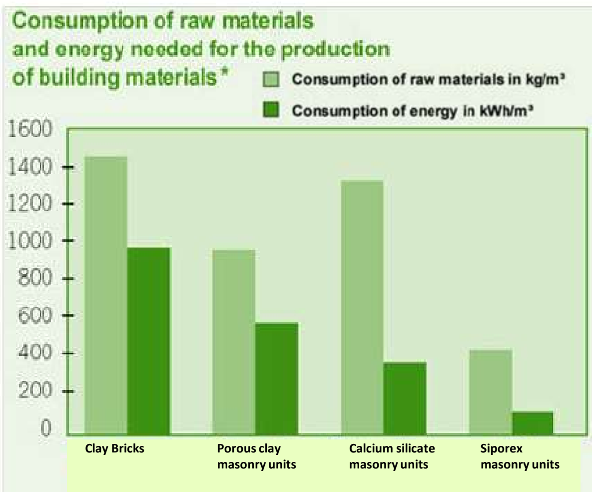


Flat No. 401		Base Case (AAC Block + AAC Slab)			Option 1 (AAC Block + RCC Slab)			Option 2 (RCC Wall + RCC Slab)		
		Living Room	Bed Room	Total	Living Room	Bed Room	Total	Living Room	Bed Room	Total
Comfort	No of Hrs in Yr	3226	2294	5520	2774	1792	4566	2561	1774	4335
25^0C to 30^0C	%	36.83%	26.19%	63.01%	31.67%	20.46%	52.12%	29.24%	20.25%	49.49%
Comparative Comfort Levels		**21% More comfort than Option 1 and 28% More comfort than Option 2**			**17% Less comfort than Base Case and 5% More comfort than Option 2**			**22% Less comfort than Base Case and 5% Less comfort than Option 1**		

In flat No. 401, habitable rooms would experience much higher comfortable hours in a year for Base case than other two options. ***Thus, Base Case has much better Thermal performance.***
Option 2 (i.e. RCC Wall + RCC Slab) would experience maximum thermal discomfort.

SUSTAINABLE BENEFITS OF '3-S' PREFAB STRUCTURE

- Reduces Air Pollution at Construction sites because of site activity is minimal to erection and jointing
- Use of fully "Cured" and "Matured" components considerably reduces water consumption
- High thermal insulation results in achieving energy efficiency
- Eco Friendly



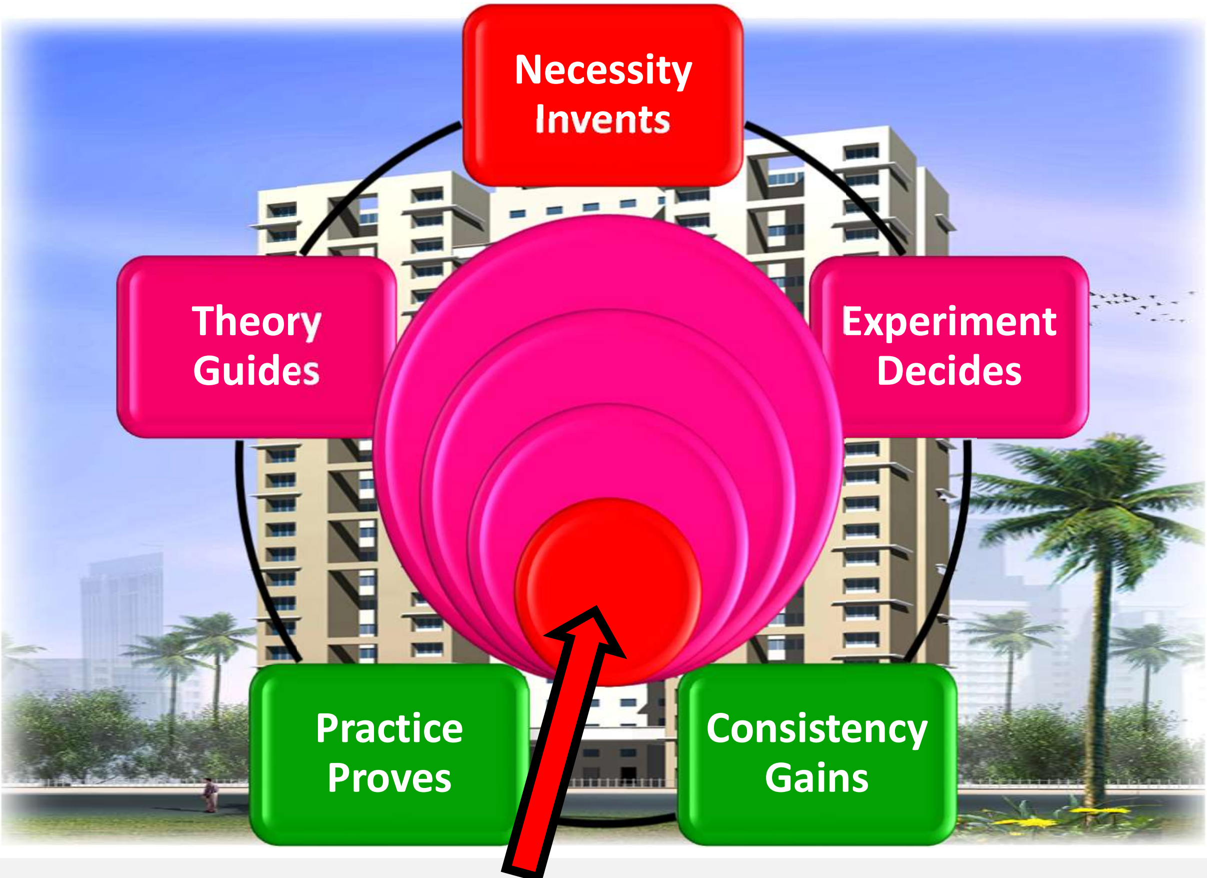
Environmental sustainability

- Siporex is made of natural raw materials that are found in abundance.
- Since Siporex is made of sand, lime, cement and water is non-toxic and environmentally safe and does not give off any harmful emissions during production.
- There is no waste in the production process.

Residential apartments and construction sector as a whole are a major contributor to the formation of 'Green House Gases' in the atmosphere i.e. 'Global Warming'.

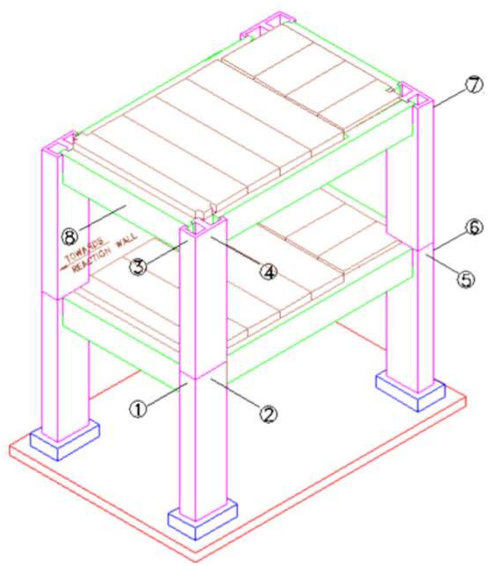
'3-S' Prefab addresses to this burning issue and contributes to reduce Global Warming.

LAB TESTED, FIELD TESTED & TIME-TESTED SUSTAINABLE PREFAB



Technology supported by advance performance tests that stand the test of time and gain the trust of all.

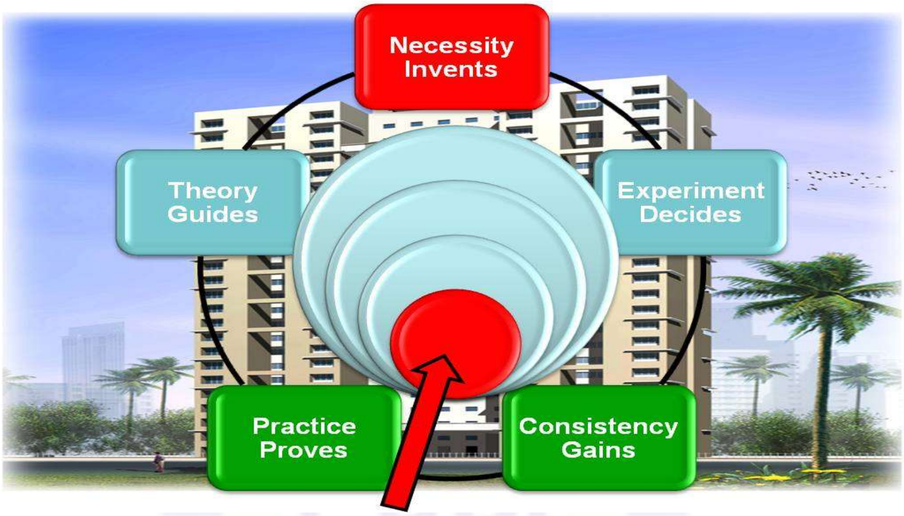
LAB TESTED, FIELD TESTED & TIME-TESTED SUSTAINABLE PREFAB



3-S PREFAB TECHNOLOGY

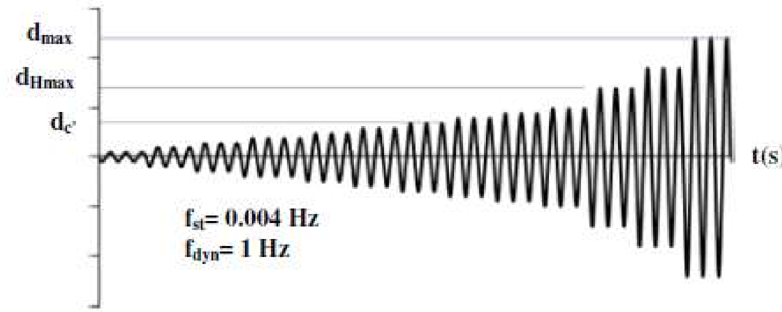
CSIR-CBRI's CONTRIBUTION TO PREFAB

Seismic and Fire Resiliency Evaluation

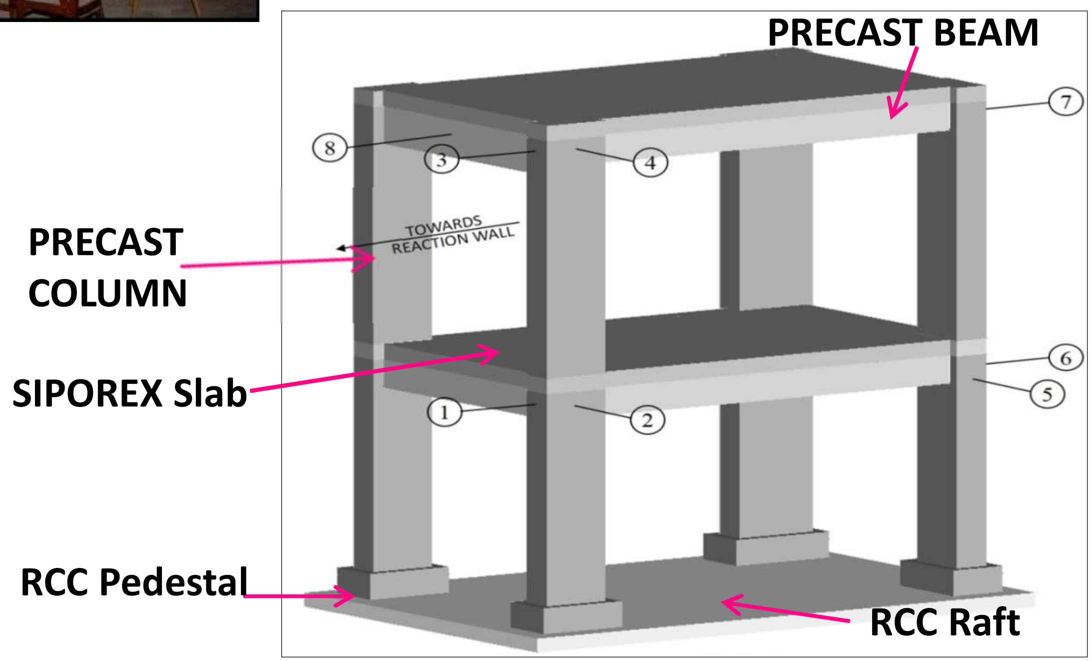


Full-Scale Test on Two Storied Prefab RC Building (3S Technology)

TEST SET- UP FOR '3-S' PREFAB BUILDING



Lateral cyclic displacement time history



Location of LVDTs

'3-S' PREFAB BUILDING

CRACK PATTERN FOR '3-S' PREFAB BUILDING

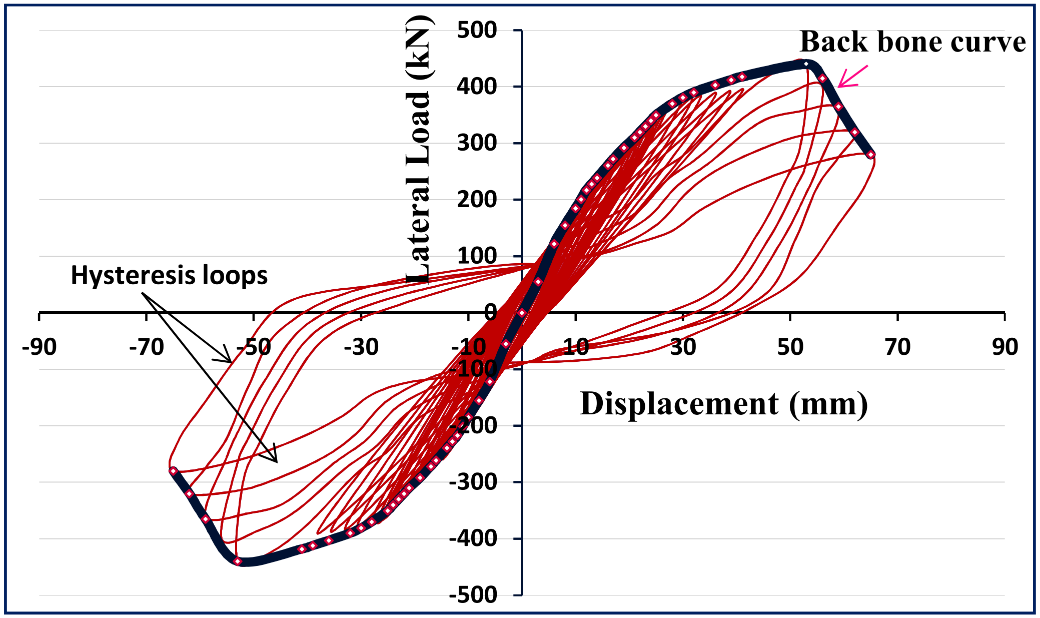
Crack at beam-column junction- outer face

Wide cracks at beam-column junction- inner face

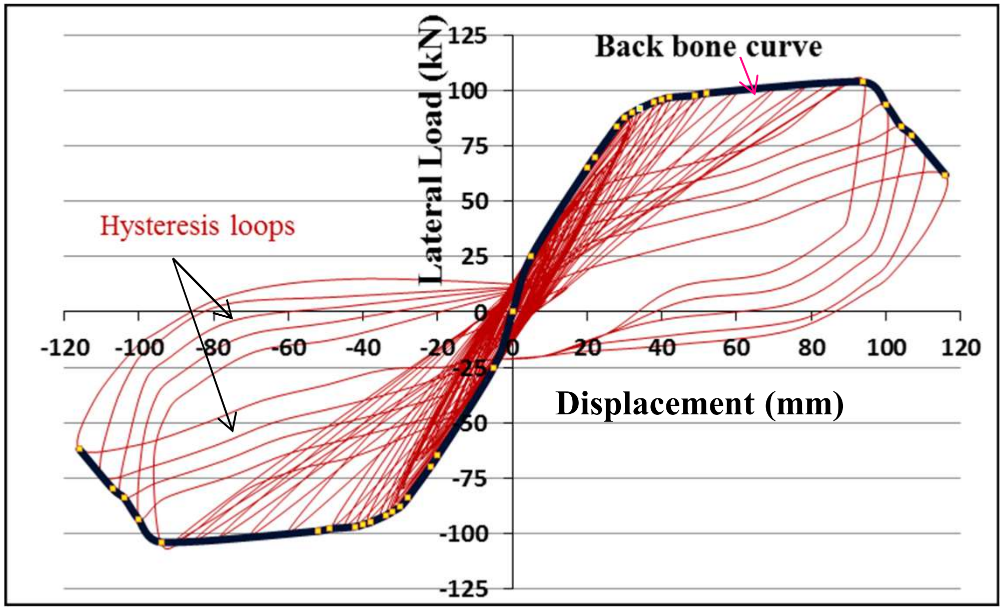
Minor horizontal cracks at junction of pedestal and column

Cracks on mid-span of column at higher drift

HYSTERESIS CURVE FOR '3-S' PREFAB BUILDING



First Floor Level

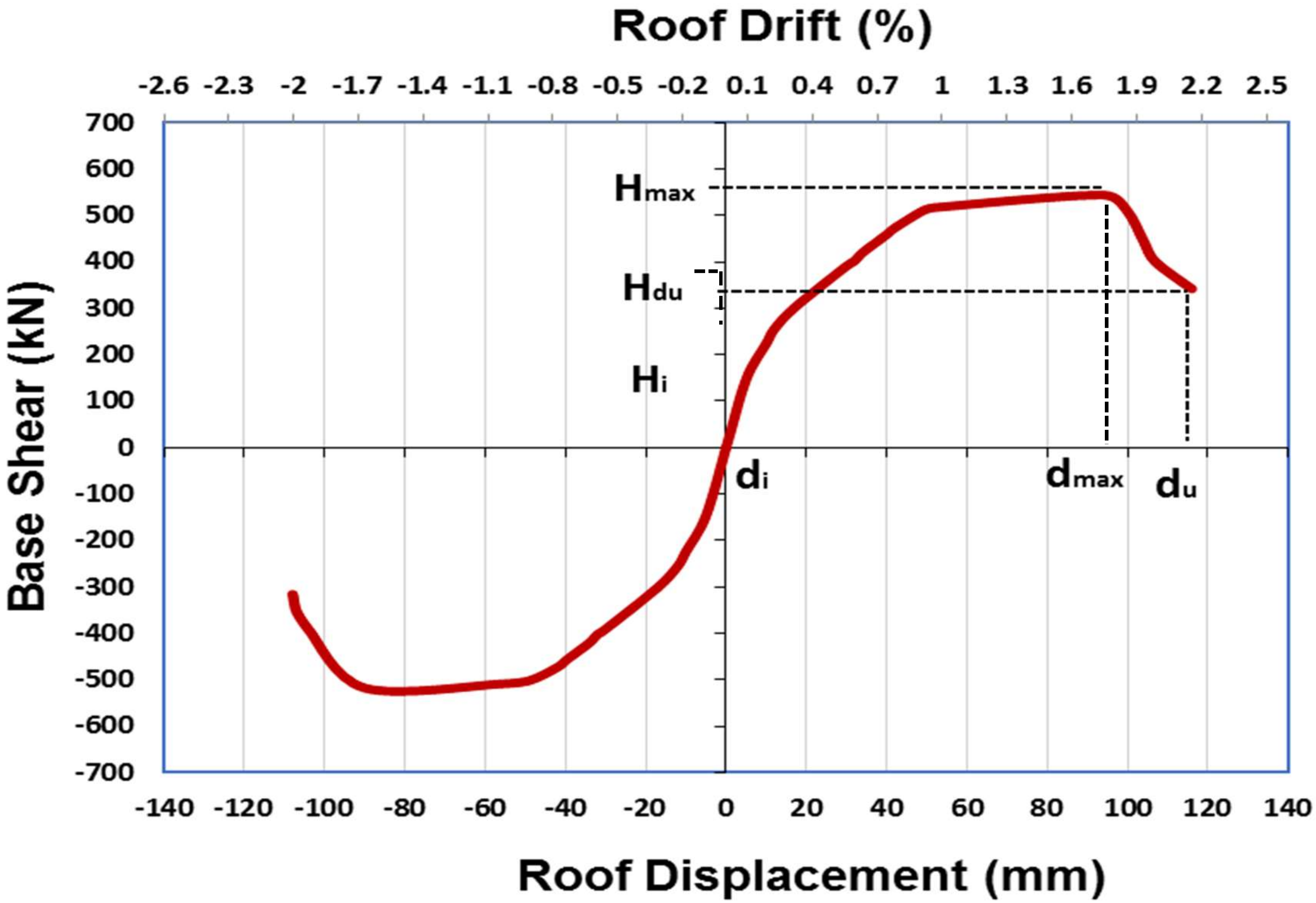


Second Floor Level

'3-S' PREFAB BUILDING

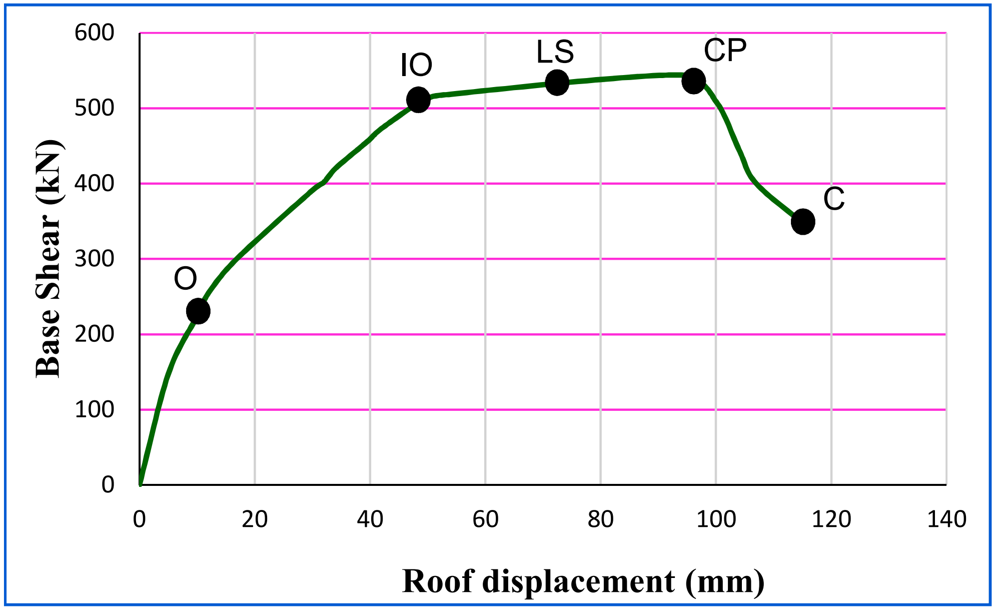
CAPACITY CURVE FOR '3-S' PREFAB BUILDING

3-S' PREFAB BUILDING

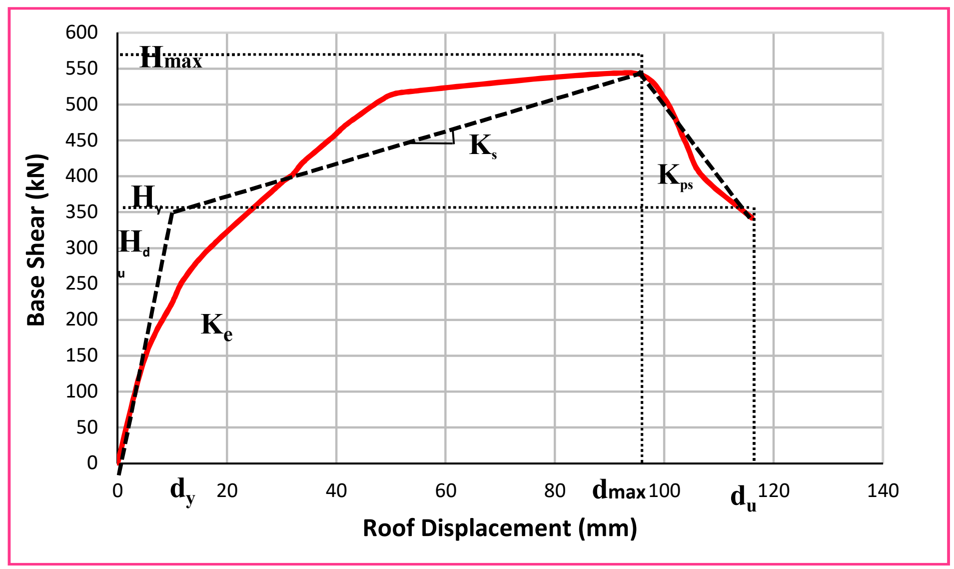


Ultimate Collapse Load	: 544 kN
Displacement at Maximum Load	: 96 mm
Inter-storey Drift at Collapse Load	: 1.78%

‘3-S’ PREFAB BUILDING



Performance levels for the tested ‘3-*S*’ prefabricated building



Simplified tri-linear idealization of the capacity curve and structural stiffness

Wide Acceptance

'3-S' PREFAB

- CLIENT :

Andhra Pradesh Rajiv Swagruha Corporation Limited

- AT HYDERABAD
- 30 MONTHS
- 64,00,000 SFT
- DESIGN & BUILD TURNKEY CONTRACT

S+14 STOREYED MASS HOUSING PROJECT

PREFAB SUSTAINABLE TECHNOLOGY

Wide Acceptance

'3-S' PREFAB

- CLIENT :

म्हाडा MHADA

- AT GOREGAON, MUMBAI
- DEC'2004 COMPLETION
- 11,16,850 SFT
- DESIGN & BUILD TURNKEY CONTRACT

S+7 STOREYED MASS HOUSING PROJECT

Wide Acceptance

'3-S' PREFAB

- CLIENT :

म्हाडा MHADA

- AT VERSOVA, MUMBAI
- DEC'2008 COMPLETION
- 10,98,665 SFT
- DESIGN & BUILD TURNKEY CONTRACT

S+15 STOREYED MASS HOUSING PROJECT



Wide Acceptance

'3-S' PREFAB

- CLIENT :

म्हाडा MHADA

- AT MAZGAON
  KURLA
  WORLI
  LOWER PAREL
  SEWARI
  PRABHADEVI
  KANDIWALI
  GOREGAON
  BYCULLA
- 41,98,950 SFT
- DESIGN & BUILD
  TURNKEY
  CONTRACT

S+24 STOREYED MASS HOUSING PROJECTS ON MILL LANDS IN MUMBAI

Wide Acceptance

'3-S' PREFAB

- CLIENT : CIDCO WE MAKE CITIES
- AT KHARGHAR, NAVI MUMBAI
- 12,52,400 SFT
- DESIGN & BUILD TURNKEY CONTRACT

S+4 / S+7 STOREYED MASS HOUSING PROJECT


KH1


KH2


KH3


KH4

Wide Acceptance

'3-S' PREFAB

- CLIENT :

म्हाडा MHADA

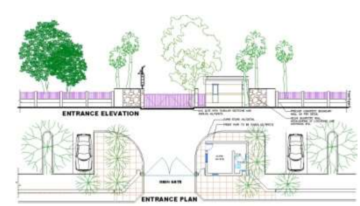
- AT MANKHURD, MUMBAI
- JUN'1999 COMPLETION
- 16,67,970 SFT
- DESIGN & BUILD TURNKEY CONTRACT

S+7 STOREYED MASS HOUSING PROJECT

Wide Acceptance

'3-S' PREFAB

- CLIENT:
- AT DELHI (ROHINI, NARELA & DWARKA)
- 64,92,888 SFT
- DESIGN & BUILD TURNKEY CONTRACT
- PROJECT JUST STARTED



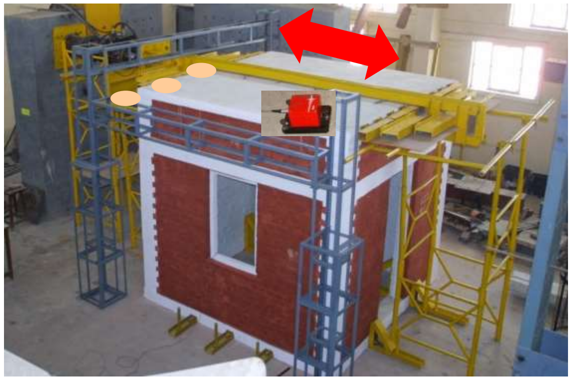
PREFAB SUSTAINABLE TECHNOLOGY

CONFINED MASONRY

MODERATE COST - EARTHQUAKE RESISTANT BUILDING

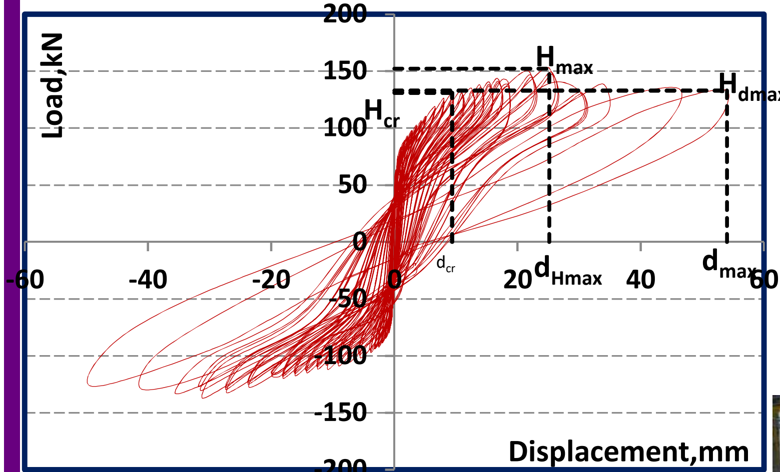
CONSTRUCTION SEQUENCE

- **With enhanced seismic performance. Makes use of locally available construction material, preferably lower level of skills and cost effective.**
- **Increase in strength and ductility by 3.42 and 4.29 times as compared to URM.**



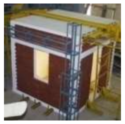
FULL-SCALE TEST

CRACK PATTERN

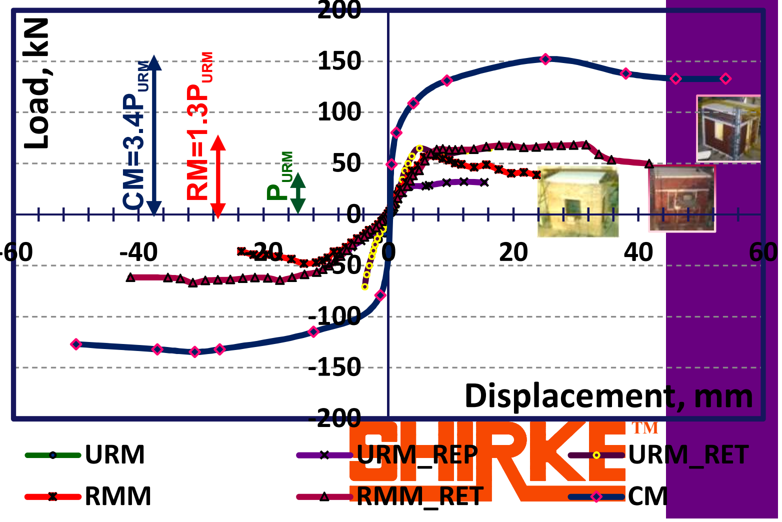


URM: UNREINFORCED MASONRY

RMM: REINFORCED MASONRY

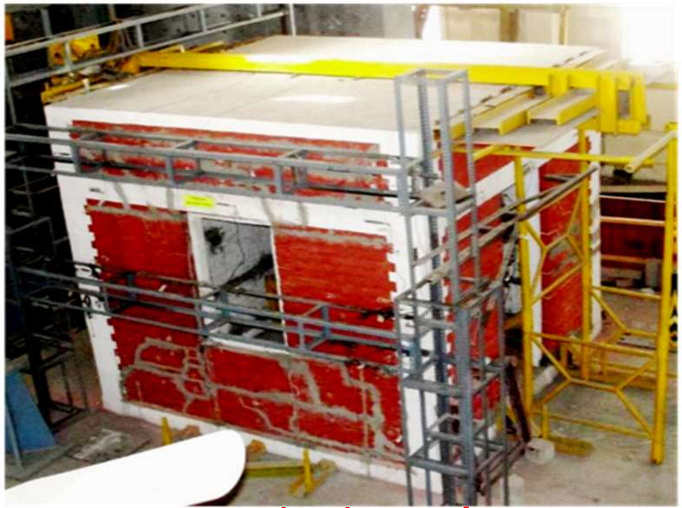


CM: CONFINED MASONRY



STRENGTHEING OF DAMAGED CONFINED MASONRY BUILDING


Cracks in CM building Model


Grouting in Cracks


Application of Plastic Cement Bag Mesh

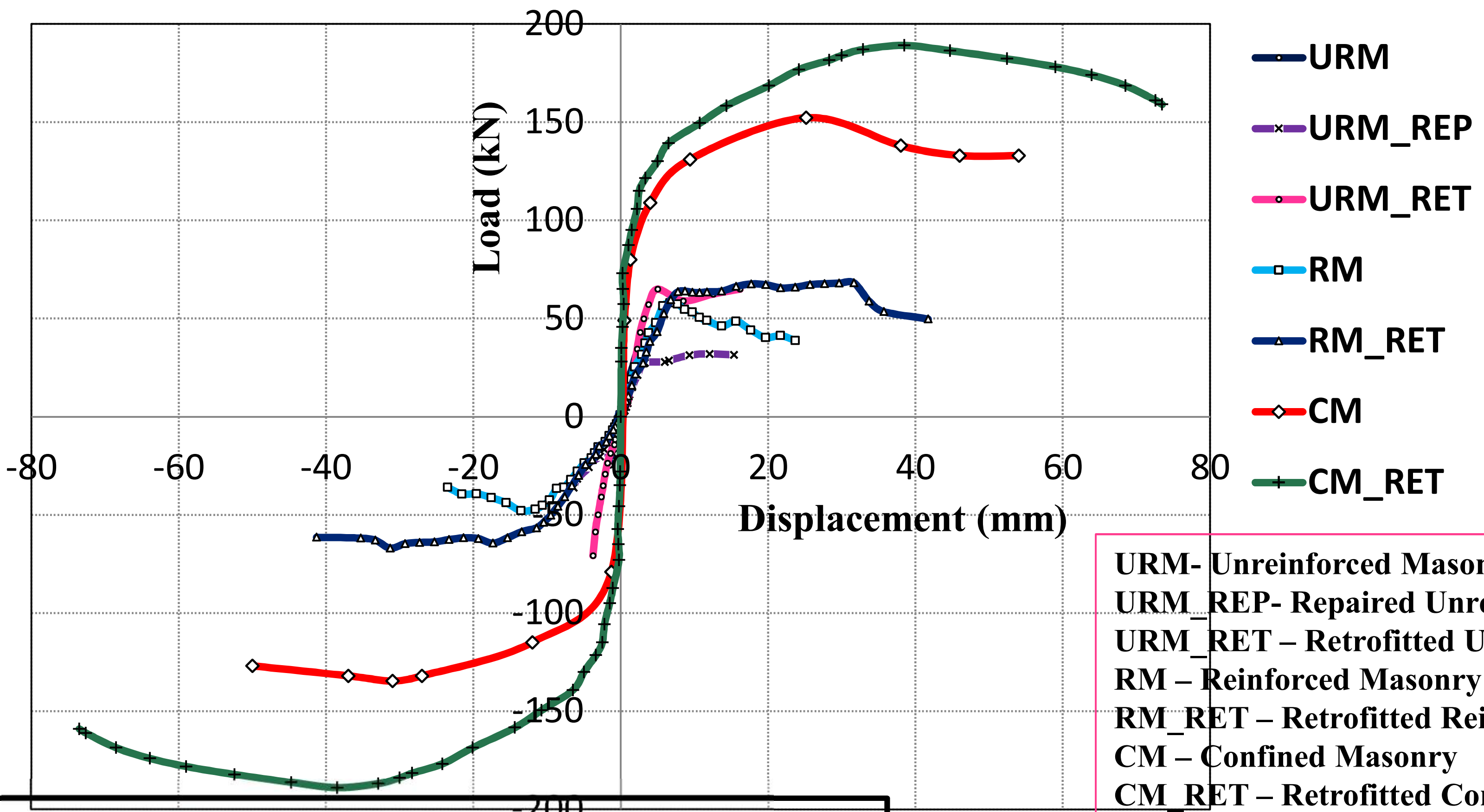

Plastering and Curing

SHIRKE™

DAMAGED CM_RET BUILDING

SHIRKE™

LOAD-DISPLACEMENT FOR TESTED MASONRY BUILDINGS



URM- Unreinforced Masonry
URM_REP- Repaired Unreinforced Masonry
URM_RET – Retrofitted Unreinforced Mason
RM – Reinforced Masonry
RM_RET – Retrofitted Reinforced Masonry
CM – Confined Masonry
CM_RET – Retrofitted Confined Masonry

Significant improvement in:

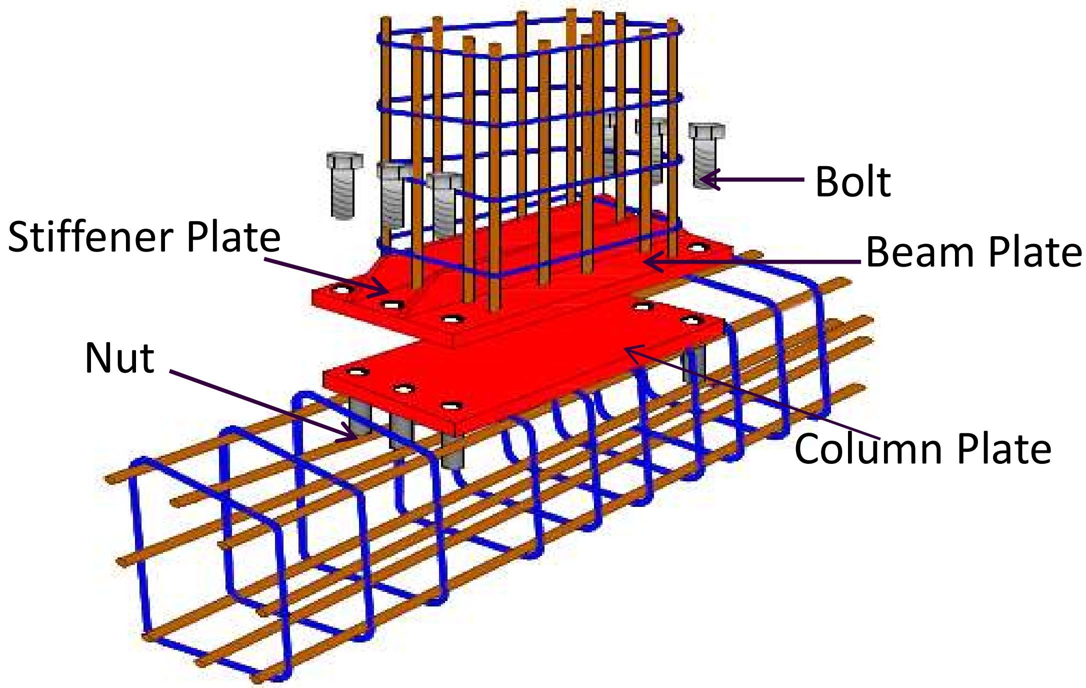
- Lateral Strength : 22%
- Stiffness : 15%
- Ductility : 23%
- INCREASE IN LATERAL STRENGTH BY 4.22 TIMES AS COMPAIRED WITH UNREINFORCED MASONRY BUILDING

Provision results in:

- Confinement of damaged masonry.
- Controlling damage.
- Collapse prevention.

INNOVATIVE CONNECTIONS FOR PRECAST STRUCTURAL COMPONENTS

PRECAST BEAM-COLUMN CONNECTIONS

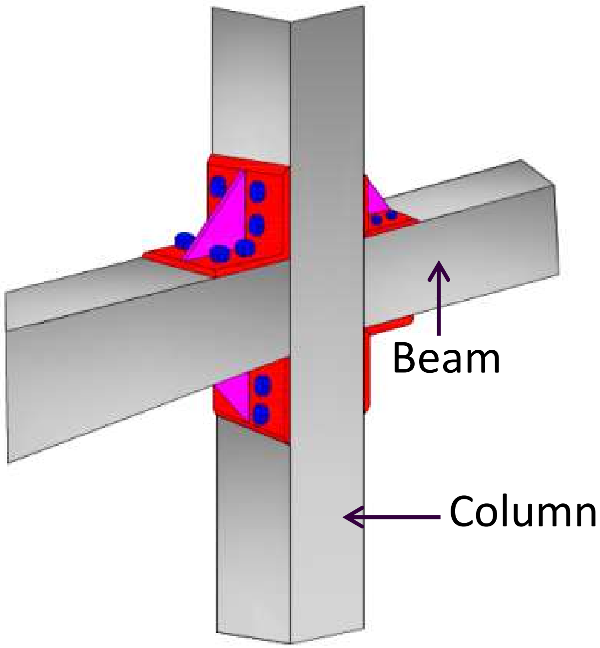


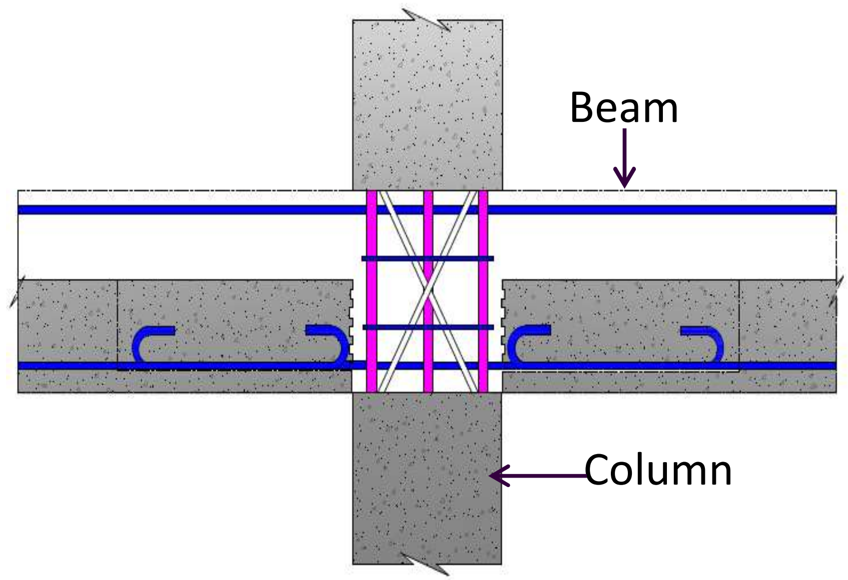
Bolted Moment Connection

- ❑ **20 mm mild steel plates fixed at beam and column face**
- ❑ **Beam plate stiffened by two small plates (10 x 50 mm)**
- ❑ **Column plate fastened to concrete through anchorage rods**
- ❑ **20% higher lateral load carrying capacity**

Pul and Şentürk (2017)

PRECAST BEAM-COLUMN CONNECTIONS





Steel angle at beam-column joint

- Beam-column connected using steel angles
- Steel angles stiffened using plates
- Steel angle anchored into concrete using HSFG bolts

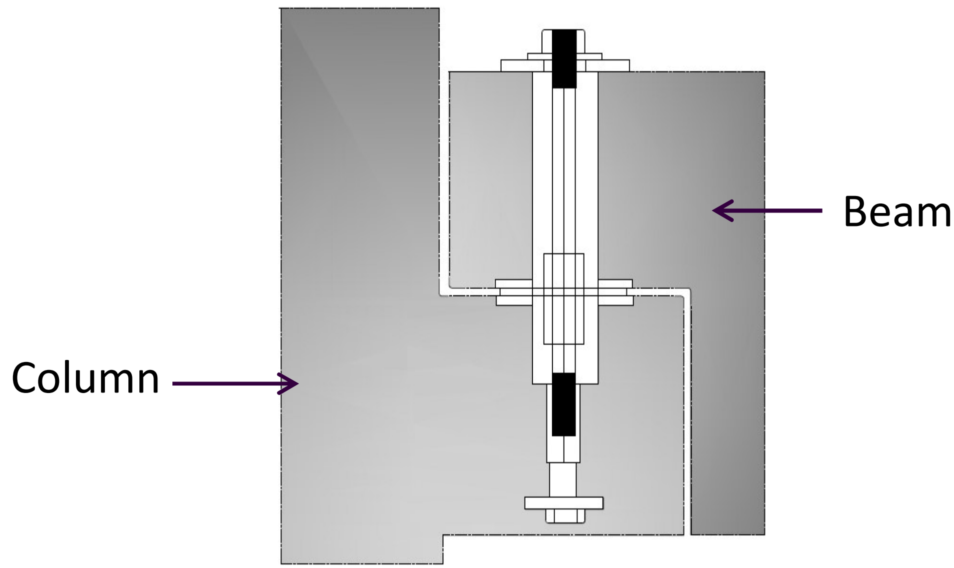
Aninthaneni and Dhakal (2014)

Ductile moment resisting connection

- Diagonal bars protrude from columns
- Joint filled with cast-in-situ concrete
- Higher flexural strength, energy dissipation and initial stiffness

Parastesh et al. (2014)

PRECAST BEAM-COLUMN CONNECTIONS

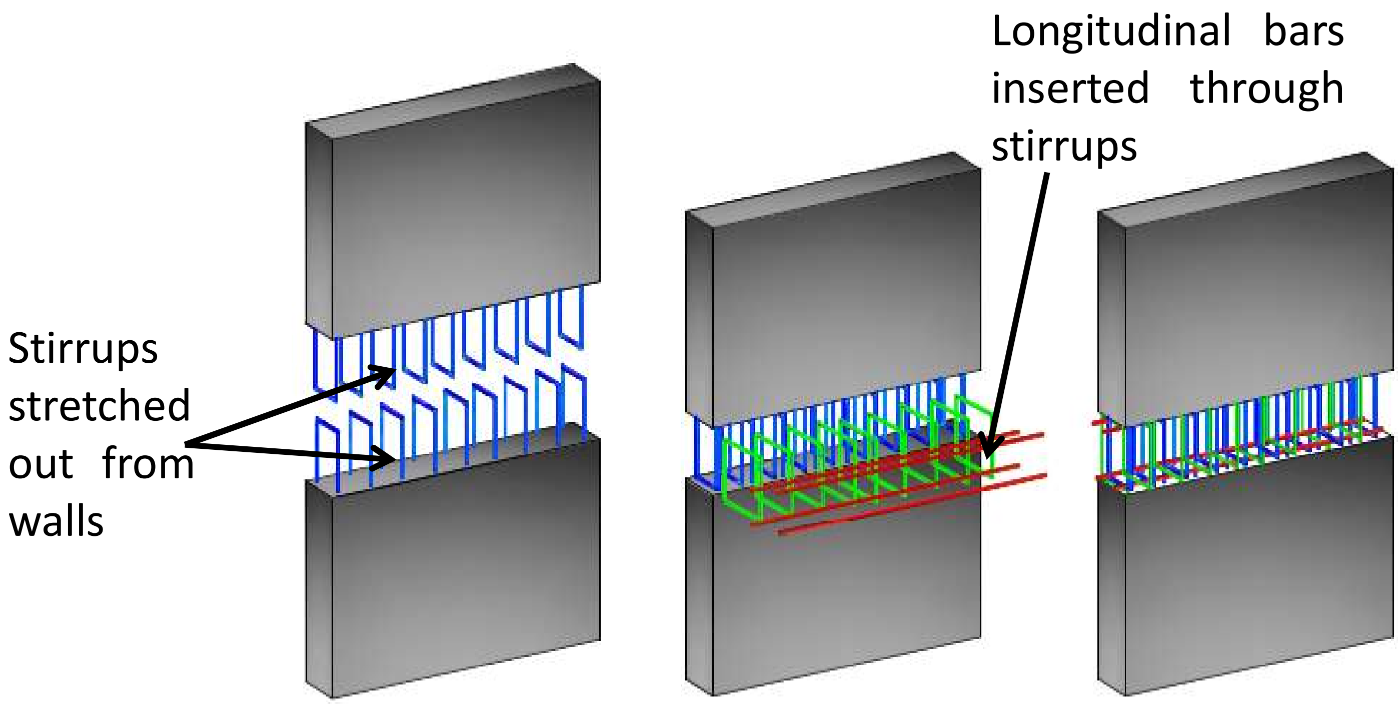


Shear connector

- ❑ **Beam rested on column capital**
- ❑ **Vertical steel dowels protruding from the column inserted into the beam sleeves**
- ❑ **3.5 times lesser joint slip as compared to hinged specimen**
- ❑ **50% higher energy dissipation as compared to hinged specimen**

Bournas and Negro (2012)

PRECAST WALL CONNECTIONS

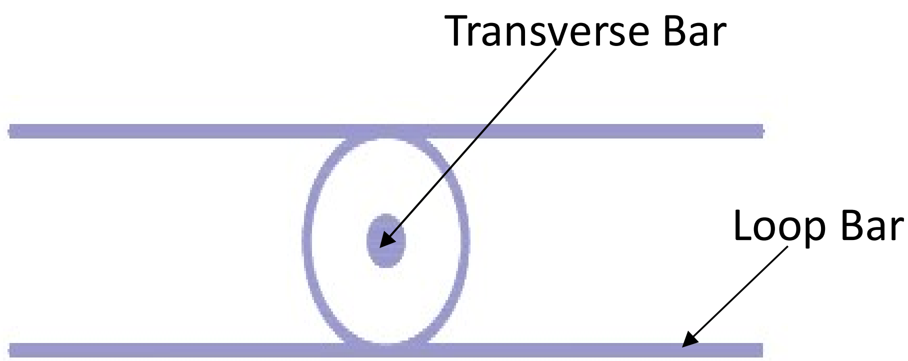


Horizontal joint connecting beam

- ❑ **Bond strengthened by chiseling the interface**
- ❑ **Inferior load bearing capacity and ductility**
- ❑ **Extent of damage reduced by increasing the depth of joint connecting beam**

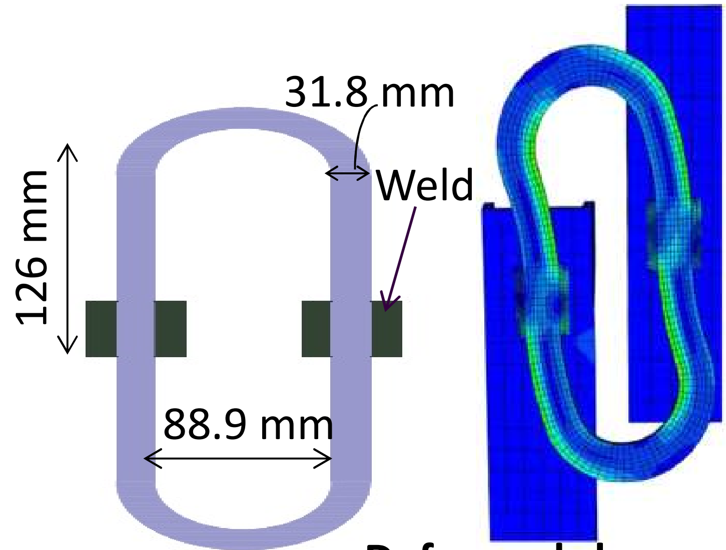
Xilin et al. (2016)

PRECAST WALL CONNECTIONS



Loop bar connection

- Steel bars protruding from the precast walls to form loops
- Transverse bar inserted between the loops
- Gap filled with concrete of adequate strength
- Efficiency depends upon embedment length and grade of loop bars.



Deformed shape from FEM analysis

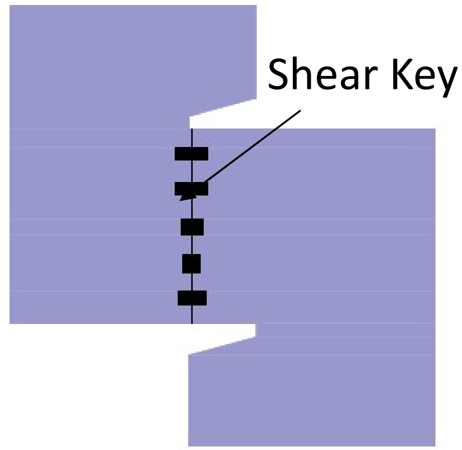
O-connector

- Mild steel oval shape connector
- Welded to wall and column
- Higher ductility and energy dissipation

Sritharan et al. (2015)

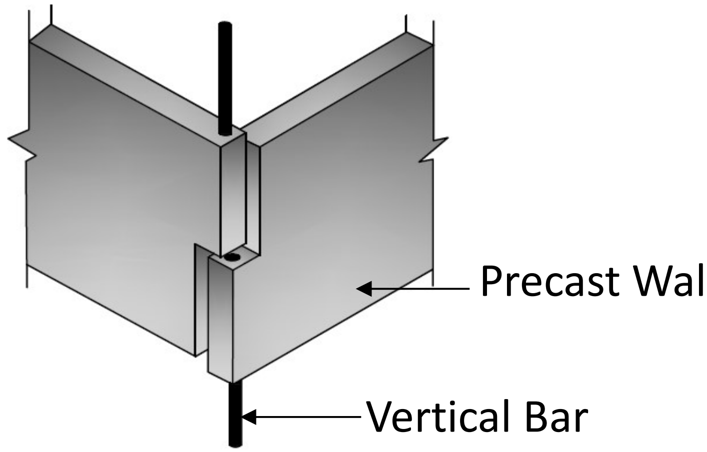
PRECAST CONNECTIONS

PRECAST WALL CONNECTIONS



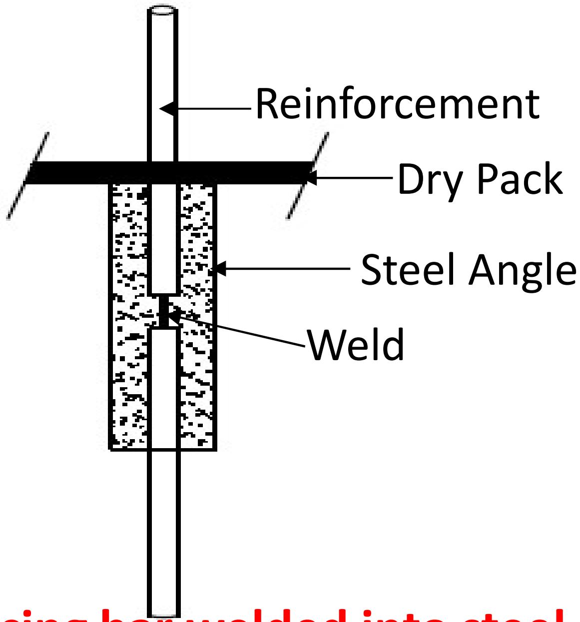
Shear key along the joint

(Rizkalla et al. 2014)



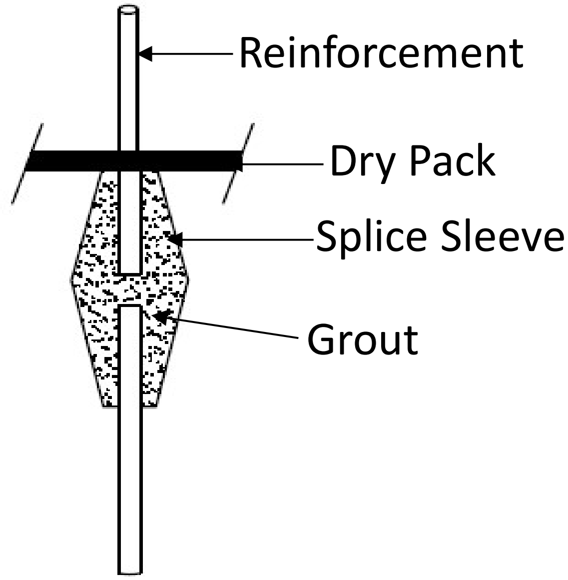
Vertical interlocking joint

(Edward et al. 1988)



Reinforcing bar welded into steel angle

(Khaled et al. 1995)

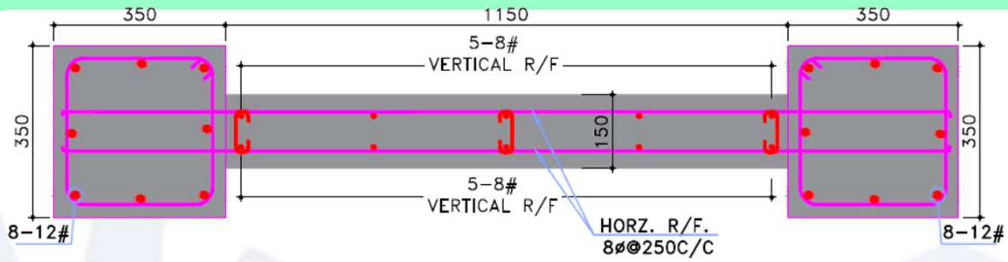


Reinforcing bar with splice sleeve

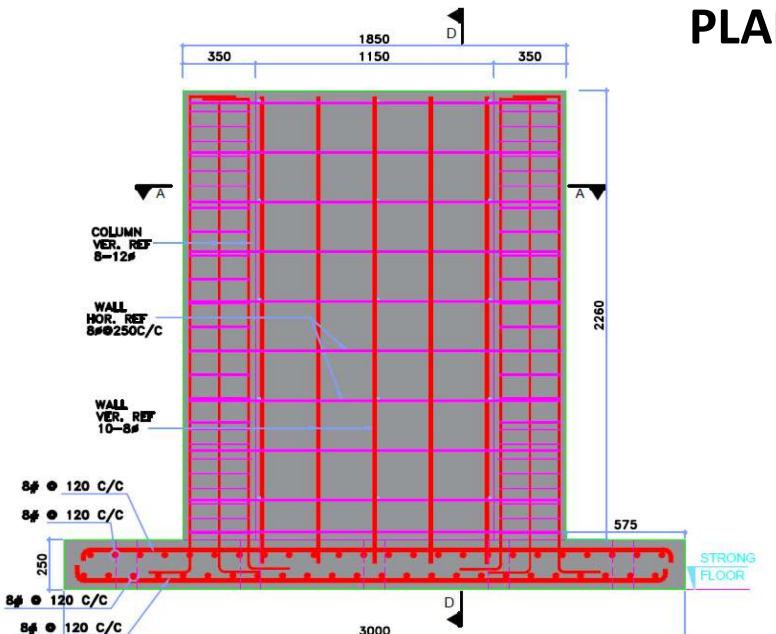
(Khaled et al. 1995)

PRECAST CONNECTIONS

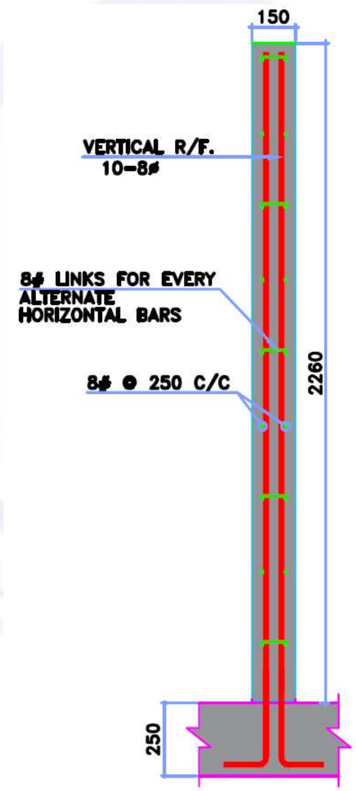
TEST MODEL-I: CAST-IN-SITU



PLAN



Elevation

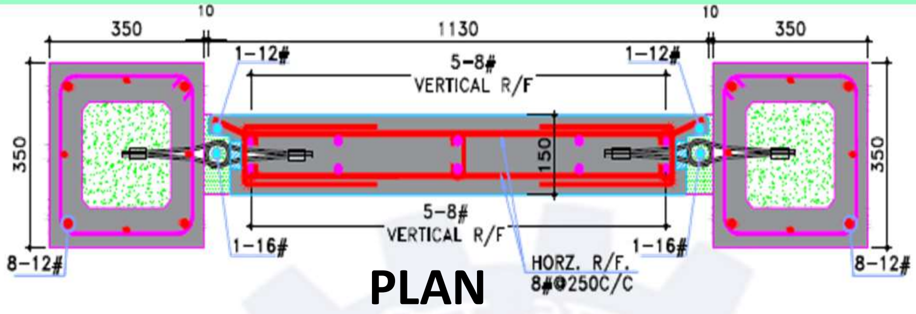


Section

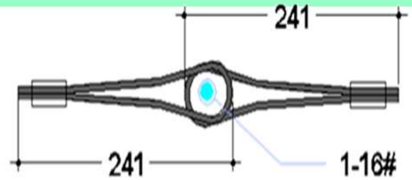
- Design of shear wall as per IS 13920 : 2016
- Design parameters:

Grade of concrete	:	M30
Grade of steel	:	Fe500

TEST MODEL-II: SOLID PRECAST WALL COUPLED WITH COLUMNS

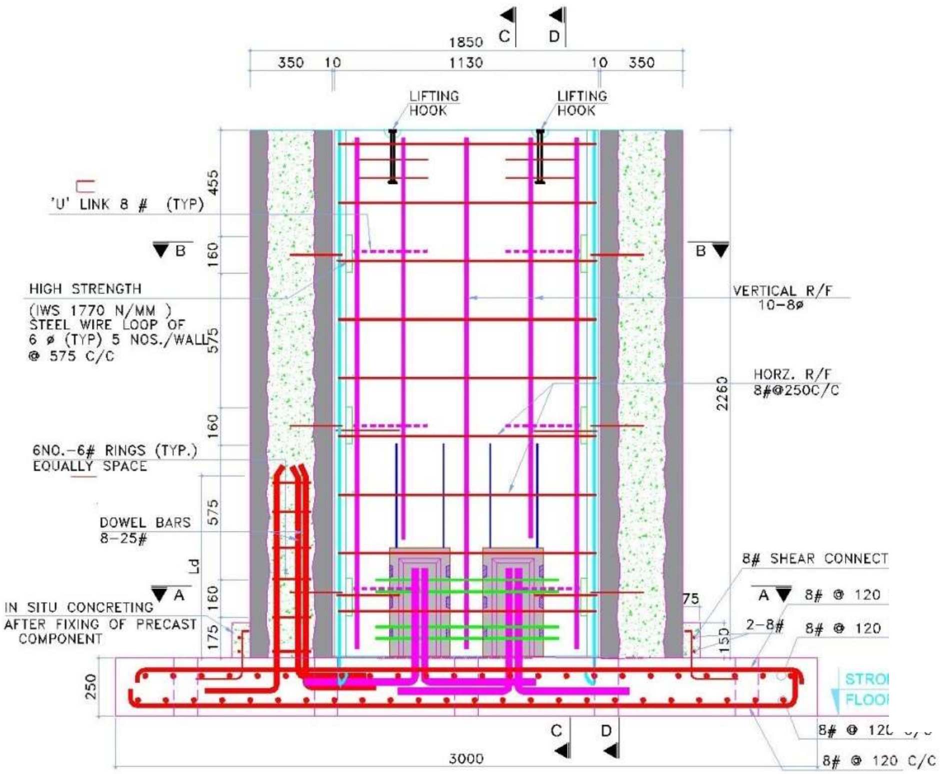


PLAN

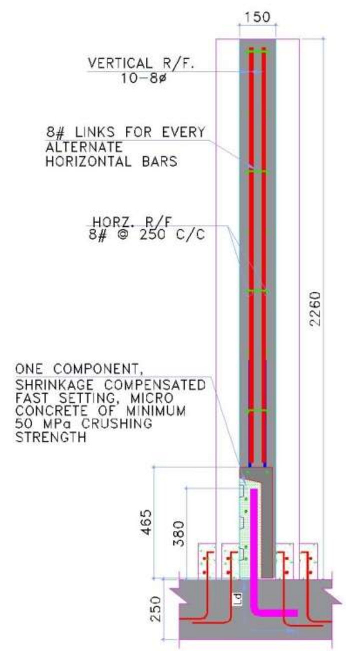


HIGH STRENGTH (1770 N/mm²) STEEL WIRE LOOP OF 6 Ø (TYP) @575 C/C

DETAILS OF LOOP BAR

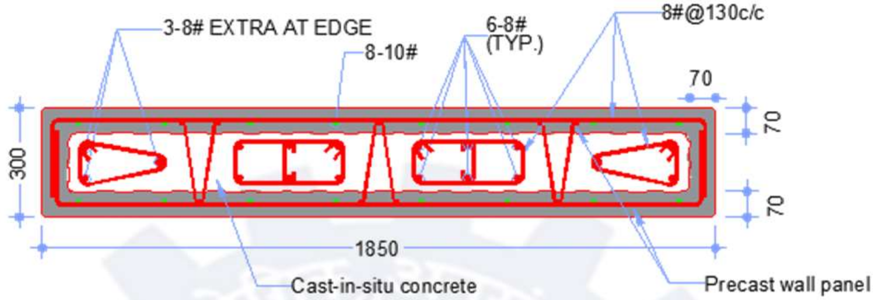


Elevation

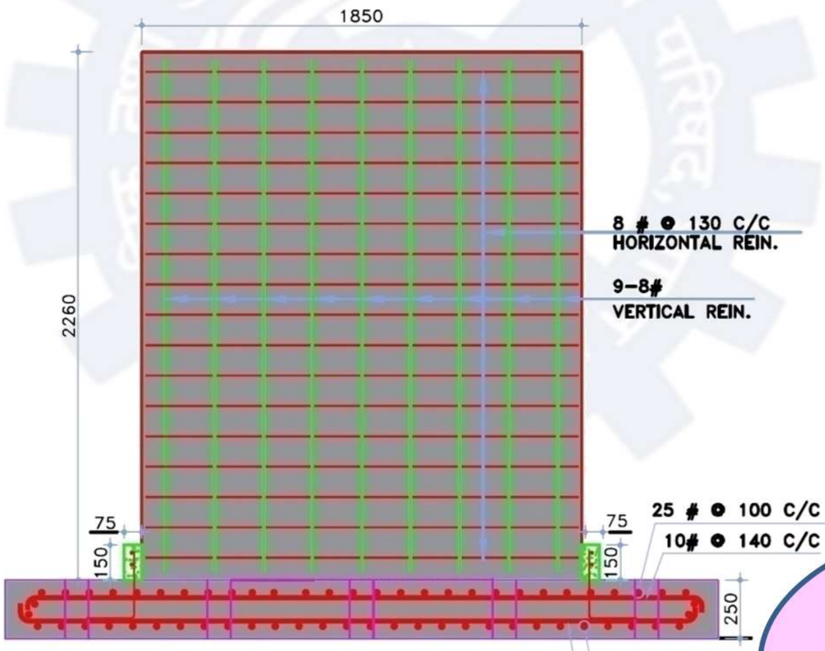


Section

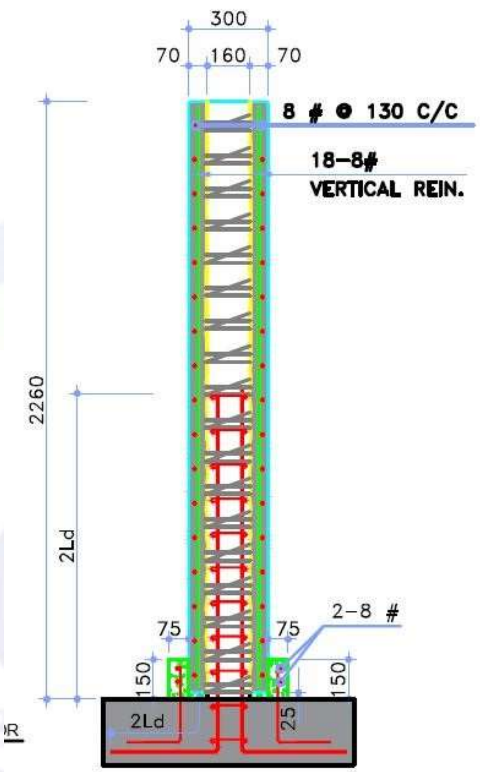
TEST MODEL-III: PRECAST DOUBLE WALL WITH HOLLOW CORE



PLAN



ELEVATION

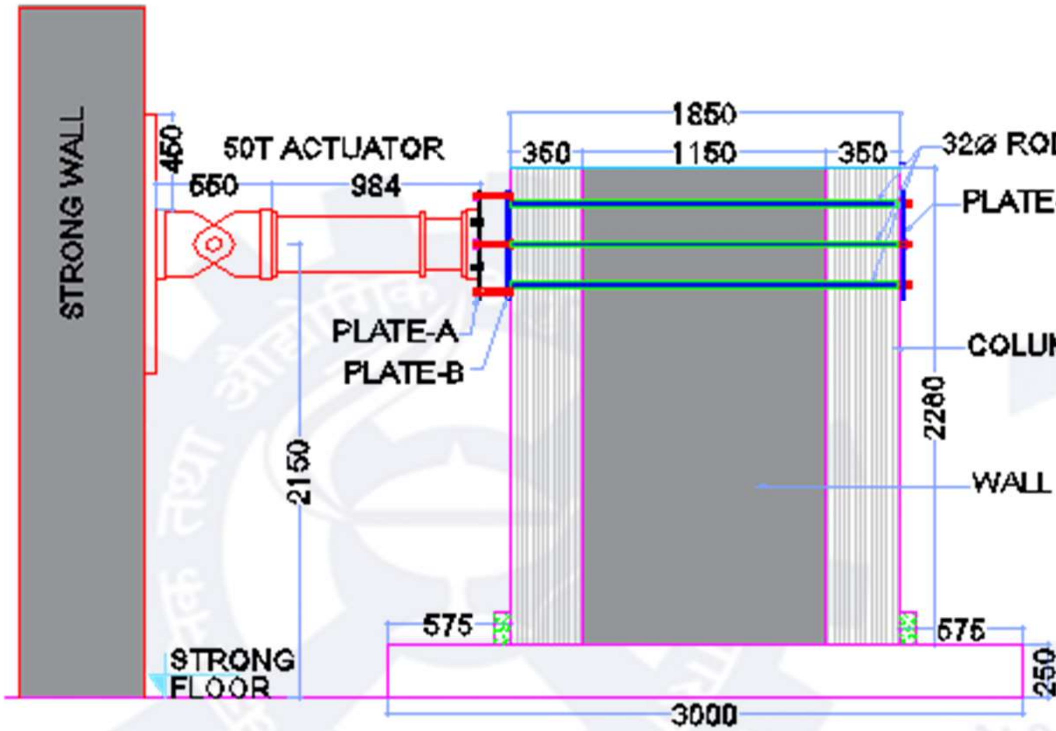


Section

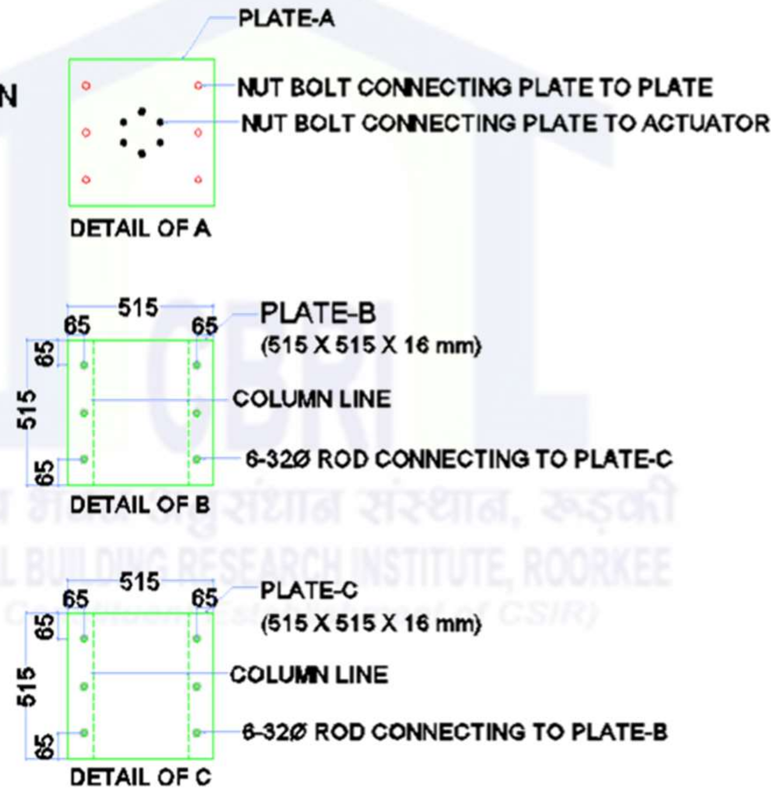
Vertical reinforcement distributed in hollow region and precast wall panels.

Reinforcement in hollow region also act as connection between wall and footing, thus minimizing the requirement of steel.

EXPERIMENTAL SETUP

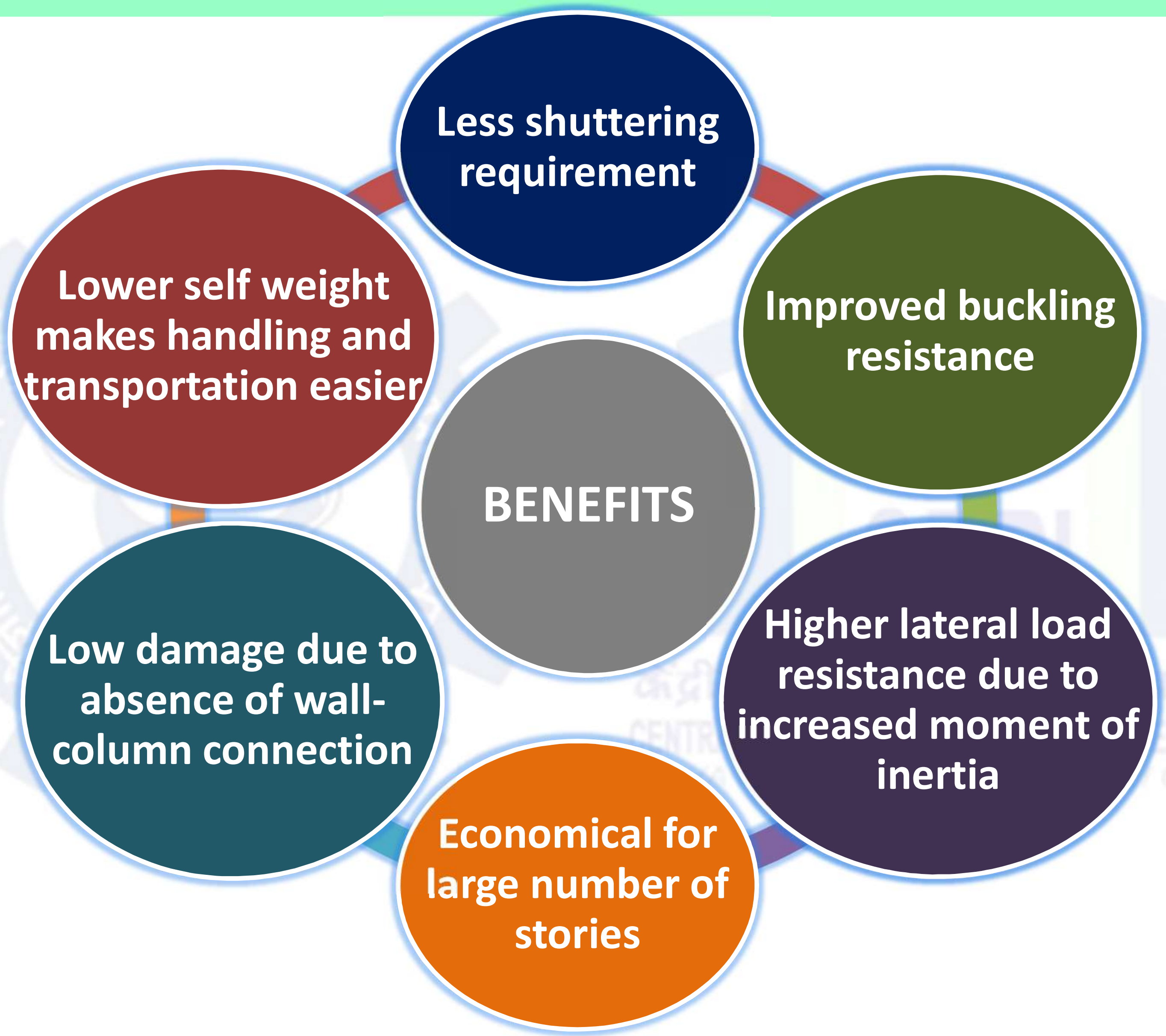


LOADING SYSTEM



DETAILS OF PLATES

BENEFITS OF PRECAST DOUBLE WALL SYSTEM

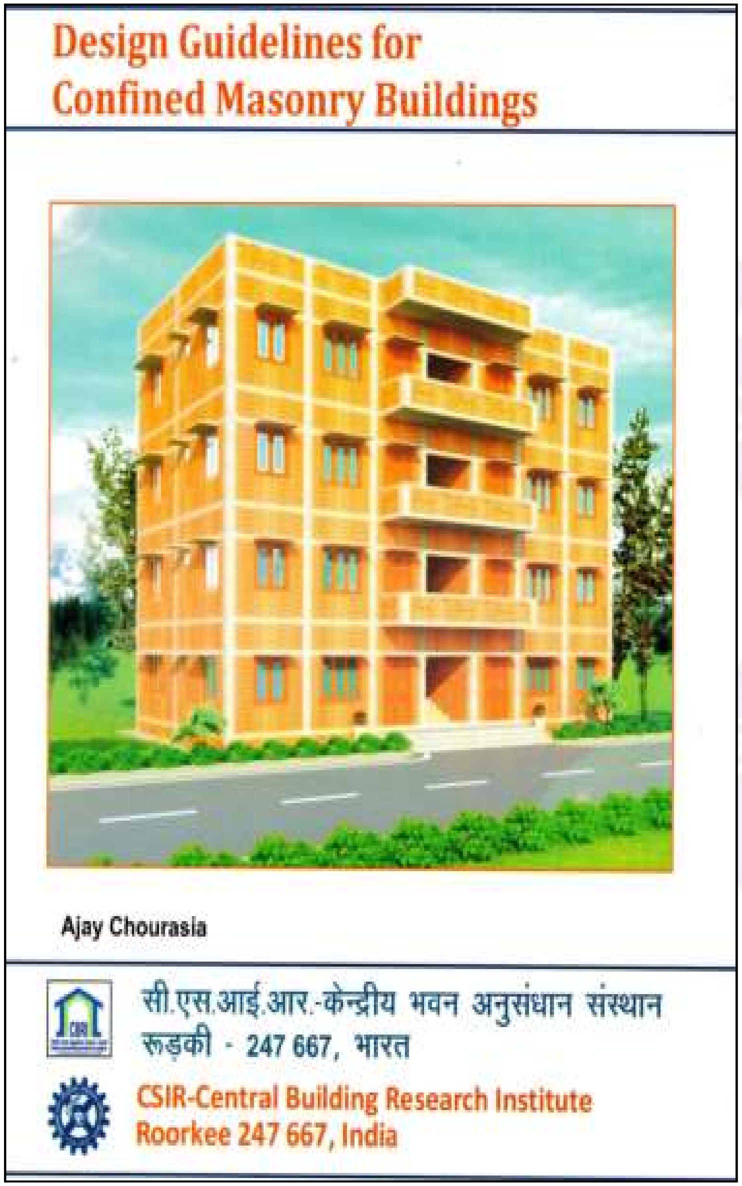


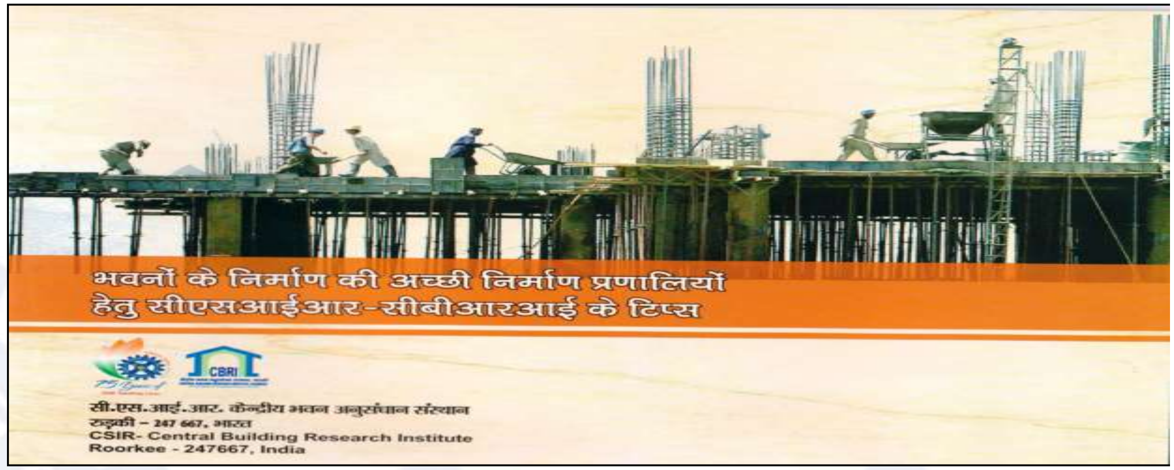
SUMMARY

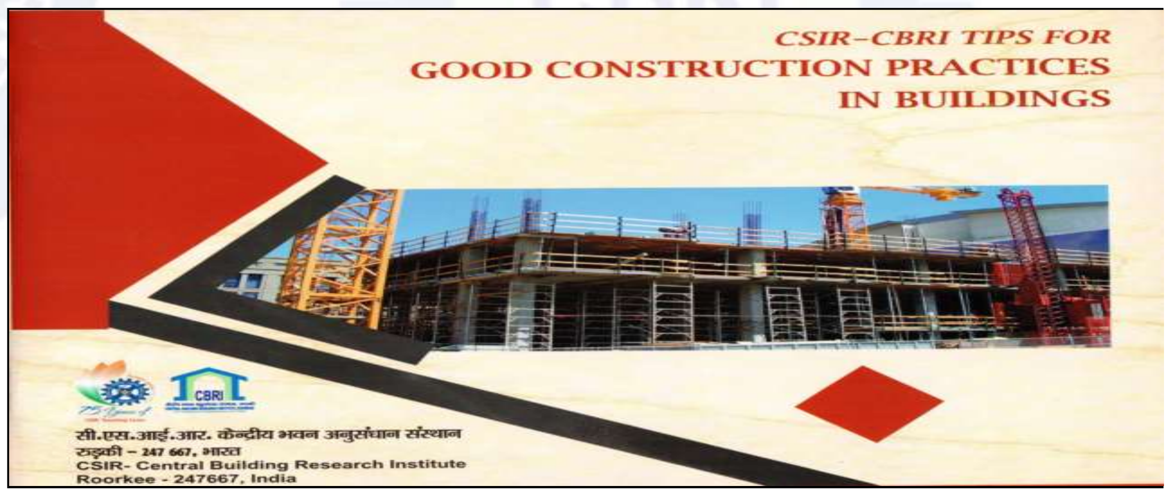
- PREFAB BUILDINGS FOR HOUSING IS A PROMISING TECHNOLOGY FOR MASS-SCALE & RAPID CONSTRUCTION
- SHOULD BE MULTI-HAZARD RESISTANT – PROVEN TECHNOLOGY
- AT COMPONENT LEVEL – CBRI DEVELOPED PRECAST BUILDING COMPONENTS
- AT SYSTEM LEVEL – PREFAB 3S TECHNOLOGY , PLASTIC-ALUMINIUM OR ALUMINIUM FORMWORK TECHNOLOGY
- LAB TO LAND
- R&D COLLABORATION : INDUSTRY AND CSIR-CBRI

WORK PACKAGES

TECHNICAL DOCUMENTS RELEASED





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JOURNEY CONTINUES TOWARDS PERFECTION

THANKS