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Review On Analysis Of Precast Concrete Structure

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Abstract - *Though the precast concrete structural systems are being widely used worldwide, in India most of the constructions are cast-in-situ concrete constructions. The tremendous growth of population in India & limited space available has led to the demand for multi-storey residential buildings. This demand can be satisfied by the utilization of factory made quality controlled precast units that provides for faster construction leading to economy. Precast concrete structural systems displaying non-linear response characteristics can be broadly classified into two main categories as equivalent monolithic systems and jointed systems. Existence of a topping slab resulted in improvements in the cracking moment and initial stiffness of hollow-core units. In the present study, seven types of simple mechanical precast beam column connections and a reference monolithic specimen were considered. The monolithic specimens cast in two numbers with the reinforcement detailing as per IS 13920:1993.The seven precast beam column connections were grouped into three categories. The specimens were classified into three groups with two numbers in each group. They are Type-I connections-bolt and rod connections, Type-II Connection: cleat angle and stiffened cleat connections and Type-III connections: dowel connections.*

Keywords- *Precast concrete, Topping slab, Beam column connection, Cast-in-situ concrete , Hollow-core unit*

I. INTRODUCTION

The precast concrete industry is largely dominated by Government initiated projects for infrastructural development. However, these are also being extensively used for residential (low and high rise) and commercial constructions because of their various favorable attributes. The efficiency, durability, ease, cost effectiveness, and sustainable properties of these products have brought a revolutionary shift in the time consumed in construction of any structure. Construction industry is a huge energy consuming industry, and precast concrete products are and will continue to be more energy efficient than its counterparts. The wide range of designs, colours and structural options that these products provide is also making it a favorable choice for its consumers. **Precast concrete** is a construction product produced by casting concrete in a reusable mold or "form" which is then cured in a controlled environment, transported to the construction site and lifted into place. Many state and federal transportation projects in the United States require precast concrete suppliers to be certified by either the Architectural Precast Association (APA), National Precast Concrete Association (NPCA) or Precast Prestressed Concrete Institute (PCI).

Materials used for precast concrete structures are concrete, steel reinforcement, structural steel & bolts and Non cementitious material(Elastomeric bearings for Neoprene, rubbers & mastics are used for soft bearings pads, backing strips,etc). There are many different types of precast concrete forming systems for architectural applications, differing in size, function, and cost. Precast architectural panels are also used to clad all or part of a building facades or free-standing walls used for landscaping, soundproofing, and security walls, and some can be prestressed concrete structural elements. Storm water drainage, water and sewage pipes, and tunnels make use of precast concrete units. Using a precast concrete system offers many potential advantages over onsite casting. Precast concrete production is performed on ground level, which helps with safety throughout a project. There is greater control over material quality and workmanship in a precast plant compared to a construction site. The forms used in a precast plant can be reused hundreds to thousands of times before they have to be replaced, often making it cheaper than onsite casting when looking at the cost per unit of formwork.

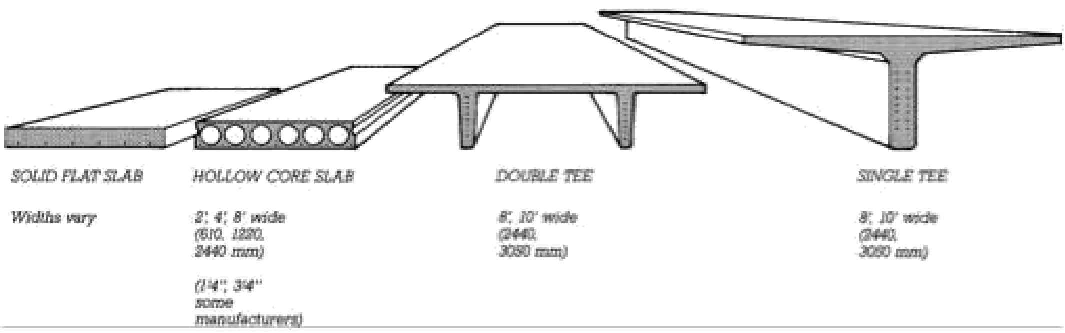

Figure 1.1 Precast concrete slab

II. LITERATURE REVIEW

2.1 Marco Breccolotti , Santino Gentile , Mauro Tommasini , Annibale Luigi Materazzi , [2016] Beam-column joints in continuous RC frames: Comparison between cast-in-situ and precast solutions. Nevertheless, cast-in-situ solutions intrinsically allow building moment resisting frames, a behaviour that is usually hard to achieve using precast elements. In this paper a technical solution able to offer both high strength and ductility, simplicity of construction of the prefabricated elements and ease of assembly on site is presented. The solution realizes the continuity between beam and column by means of loop splices and cast-in-place concrete with steel fibers to improve the ductility of the concrete struts in the wet joint. It is based on prefabricated beams and columns with protruding bars that are connected in situ by means of a concrete wet joint with steel fibres to moderately increase the ductility properties of the compressed struts in the joint. The results of these tests showed that the two solutions exhibited very similar structural behaviours, with the proposed solution achieving a slightly greater strength and stiffness than those of the cast-in-situ solution without relevant modifications to the joint ductility. In detail, the arrangement of the reinforcing steel has been updated in order to avoid the yielding of the steel inside the column and to move the plastic zone inside the beam.

2.2 Nerio Tullini , Fabio Minghini Grouted sleeve connections used in precast reinforced concrete construction – Experimental investigation of a column- to-column joint. The results of an experimental campaign concerning full-scale tests on precast reinforced concrete column-to-column connections made with grouted sleeve splices are presented. The precast column units had a square cross-section with the side of 500 mmThe column-to-column connections were subjected to three monotonic tests (axial tension and four-point bending with and without axial compression) and to two cyclic tests (four-point bending and shear).In the tension test failure took place far from the interface between the precast units and highlighted the effectiveness of the stress transfer along the splice region. In all other tests, damage developed at the interface between the two units. In the bending tests with and without axial compression significant over-strengths with respect to design resistances computed for equally-reinforced monolithic members were attained.

2.3 Hetao Hou , Xiang Liu , Bing Qu Experimental evaluation of flexural behavior of composite beams with cast-in-place concrete slabs on precast prestressed concrete decks. This paper focuses on a new type of steel-concrete composite beams consisting of cast-in-place concret slabs on Precast Prestressed Concrete Decks (PPCDs). To evaluate flexural performance of such composite beams, this research team conducted an experimental investigation on twelve specimens. Test results show that the composite beams with PPCDs can exhibit desirable and stable flexural performance under monotonic loading. Based upon the test results, this paper also evaluates the influence of some key design parameters (e.g., concrete slab thickness, amount of shear studs and longitudinal reinforcement ratio) on flexural performance of the composite beams.

2.4 Donghoon Lee, Chaeyeon Lim, Sunkuk Kim [2016] CO2 emission reduction effects of an innovative composite precast concrete structure applied to heavy loaded and long span buildings. This study applied an SMART frame (CPC frame) to a car park building that requires large and heavy members, and the results were compared to the existing design. In addition, the quantity of material was estimated and converted into CO2 reduction based on the input resources to verify its reduction effect. structural frame built using innovative composite precast concrete (CPC) developed using a new concept called the SMART frame was demonstrated to require less steel materials, concrete, and forms than reinforced concrete (RC) due to its higher structural efficiency. This not only resulted in a reduction of costs, but also less CO2emissions. In this study, we analyzed the CO2emission reduction effect of an innovative composite precast concrete structure applied to heavy loaded buildings with more than 10 m long span.

2.5 Eray Baran [2015] Effects of cast-in-place concrete topping on flexural response of precast concrete hollow-core slabs. Results of a study focusing on the flexural response of precast prestressed concrete hollow-core slabs with cast-in-place concrete topping are presented. The experimental part of the study included load testing of five precast concrete hollow-core units. The numerically determined flexural response of test specimens was later compared with the experimentally obtained behavior. Results demonstrate that a major composite action is valid between the hollow-core unit and the topping slab under load levels corresponding to uncracked state of the cross section. Existence of a topping slab resulted in improvements in the cracking moment and initial stiffness of hollow-core units. The beneficial effect of topping slab on the ultimate moment capacity was observed to be limited, mainly because of the loss of composite action prior to reaching the ultimate moment capacity.

III. MATERIALS USED FOR PRECAST CONCRETE CONSTRUCTION

3.1 Concrete

Precast concrete is of the highest possible quality both in terms of strength and durability.

For the production of standard elements such as columns and beams,concrete is cast into clean steel moulds.The use of clamped vibrators tuned to the correct oscilations for the size and weight of the filled mould ensures correct compaction to a density of around 2400kg/m^3(excluding reinforcement).The resulting surface finish,results in minimum porosity for maximum durability.

Concrete strengths are made to match the optimum performance of each element,such that flexural members are produced in grade C40 concrete,while compression members are in C50 (or C60 if prestressed).

Generally concrete produced in this way is prestressed for flexural members such as floor slabs,because prestressed concrete benefits from additional strength in flexural compression,it is advantageous to use grade C60 concrete,although for certain geometry the requirement is only grade C50.

Demoulding and detensioning(i.e. transfer) of cast concrete takes place at around 18 hours.various methods to accelerate the early strength of concrete include rapid hardening portland cement,chemical accelerators and by external heating,such as steam curing and electrical heating.The most common combinations of in situ-to-precast strengths are C-25 to C-40 & C-30 to C-50/C60.

3.2 Steel Reinforcement

Steel offers high tension and shear strength to make up for what concrete lacks. Steel behaves similarly to concrete in changing environments, which means it will shrink and expand with concrete, helping avoid cracking.

Rebar is the most common form of concrete reinforcement. It is typically made from steel, with ribbing to bond with concrete as it cures. Rebar is versatile enough to be bent or assembled to support the shape of any concrete structure. Carbon steel is the most common rebar material. However, stainless steel, galvanized steel and epoxy coating can be used to prevent corrosion.

Bar diameters commonly used are 8 and 10mm for column stirrups,10 & 12mm for beam stirrups and other distribution or anti-crack bars,and 16,20,25,32 & 40mm for main flexural bars.

High tensile hot rolled ribbed bar(HT rebar) is used in 95% of cases,even in shear links where mild steel would be suitable.

Two main types of steel are used for pretensioning:

1) plain or indented(or crimped) wire
2) 7-wire helical strand(tendon)

The choice tendon is a matter of the arrangement of tendons and the correct distribution of pretensioning force in a section. Large tendons should not be placed in thin-wall sections- to avoid localized splitting & bond failure,the edge cover to tendons should be atleast twice the diameter. For this reason helical strand is preferred in larger units or where the level of prestress is high.

There is a long term loss of force in all pretensioning tendons, called ‘relaxation’. It is due to a stress relieving heat treatment process.

3.3 Structural Steel And Bolts

These include rolled rectangular & square hollow sections(RHS,SHS), solid billets,channels & angles,plates and welded-tees,etc.

Rolled steel sections & bent or flat steel plates are welded to form steel connectors in many highly stressed support situations where direct contact between concrete surfaces is to be avoided.

Hot dipped galvanized steel is used for exposed connections,such as dovetail channels for brick ties. High strength friction grip bolts are used in special circumstances where the integrity & safety of connections made with ordinary bolts in clearance holes.

3.4 Non Cementitious Material

Epoxy based mortars are used to make either partially or completely ,connections where a rapid gain in strength is required,e.g. upto 40N/mm^2 in 2-3 hours.The thermal expansion of epoxy materials is 7 times that of concrete.

Elastomeric bearings for Neoprene, rubbers & mastics are used for soft bearings pads, backing strips,etc.

IV. WHY PRECAST -ADVANTAGES

The main features of this construction process are as follows:

a) Compared to site-cast concrete, precast concrete erection is faster and less affected by adverse weather conditions.
b) Plant casting allows increased efficiency, high quality control and greater control on finishes.. This type of construction requires a restructuring of entire conventional construction process to enable interaction between design phase and production planning in order to improve and speed up construction.
c) The concrete of superior quality is produced as it is possible to have better technical control on the production of concrete in factory.
d) It is not necessary to provide joints in the precast construction.
e) The labour required in the manufacturing process of the precast units can easily be trained.
f) The moulds employed for preparing the precast units are of steel with exact dimension in all directions. These moulds are more durable and they can be used several times.
g) The precast articles may be given the desired shape and finish with accuracy.
h) The precast structures can be dismantled, when required and they can then be suitably used elsewhere.
i) The transport and storage of various components of concrete for cast in situ work are eliminated when precast members are adopted.
j) When precast structures are to be installed, it is evident that the amount of scaffolding and formwork is considerably reduced.

V. CONNECTION OF STRUCTURAL MEMBERS

The design in construction of joints and connections is the most important consideration in precast concrete structure.The main purpose is to transmit forces between structural members and to provide stability and robustness. There may be several different ways of achieving a satisfory connection,e.g. bolting,welding or grouting. The joint should not only we design to resist applied serviceability and ultimate loads, but they should be adequate in cases of abnormal loads due to fire,impact,explosions,subsidence,etc. failure of the joint should not lead to structural instability. A joint is the action of forces (eg. Tension, shear & compression) that takes place at the interface between two (or more) structural elements. In many cases there may be an intermediate medium, such as rubber steel, epoxy mortar etc. the design of connection is function of both the structural elements and of joints between them.
The most commonly used methods of connection analysis are

1. Strut and tie for the transfer of bearing forces.
2. Coupled joint for the transfer of bearing forces and/or bending and /or torsional moments and
3. Shear friction for the transfer of shear with or without compression.

Pinned connections occur mainly where vertical and horizontal elements are joint. They should allow for the roration of the bearing element without cracking to either of the joining elements.Therefore, the detailing of the interface of the contact zones in both the supported and supporting elements is important.

Slab connection using hollow core and double-Tee floors are designed as simply supported. Hollow core floors are usually laid directly on to the shelf provided by the boot of the beam but neoprene bearing pads or wet bedding onto grout is also used in certain circumstances eg: double Tee floor slabs.

Wet bedded bearings are sometimes used on refurbished beams with uneven surfaces. They are laid directly on to a dry precast beam seating. A nominal bearing length of 75mm results in a net length of 60mm after spalling allowances have been deducted.

5.1 Horizontal floor diaphragm:

In a ductile structure, diaphragm will almost always be required to remain elastic so that they can sustain their function of transferring forces to the main lateral-resisting structure and tying the building together. Usually, the seismic analysis of buildings is carried out on the assumption that deflections in the diaphragm are so small as compared with those in the main lateral load resisting structure that the diaphragm can be treated as rigid. A diaphragm is considered flexible when the midpoint displacement under lateral load exceeds twice the average displacement of the end supports. Therefore, they are designed as simple beams between end supports and distribution of the lateral forces to the vertical resisting elements on a tributary width, rather than relative stiffness. Hence, the rigidity of the diaphragm is classified into two groups on relative flexibility i.e: rigid and flexible diaphragm.

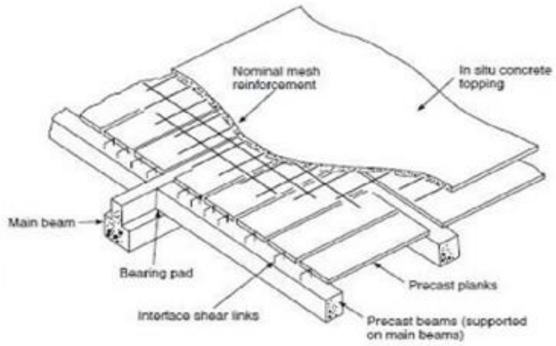

Figure 5.1(a) Composite beam and plank floor consisting beams, soffit units and cast in situ topping

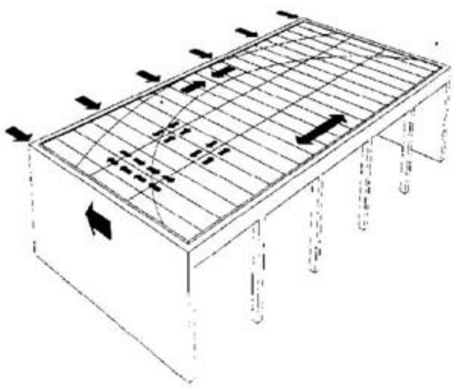

Figure 5.1(b) Floor diaphragm action

5.2 Corbel

Corbel or bracket is a reinforced concrete member is a short-haunched cantilever used to support the reinforced concrete beam element. Corbel is structural element to support the pre-cast structural system such as pre-cast beam and pre-stressed beam. The corbel is cast monolithic with the column element or wall element.

5.2.1 Behaviour Of Corbel

The followings are the major items show the behavior of the reinforced concrete corbel, as follows :

1) The shear span/depth ratio is less than 1.0, it makes the corbel behave in two-dimensional manner.
2) Shear deformation is significant is the corbel.
3) There is large horizontal force transmitted from the supported beam result from long-term shrinkage and creep deformation.
4) Bearing failure due to large concentrated load.
5) The cracks are usually vertical or inclined pure shear cracks.
6) The mode of failure of corbel are : yielding of the tension tie, failure of the end anchorage of the tension tie, failure of concrete by compression or shearinga and bearing failure.

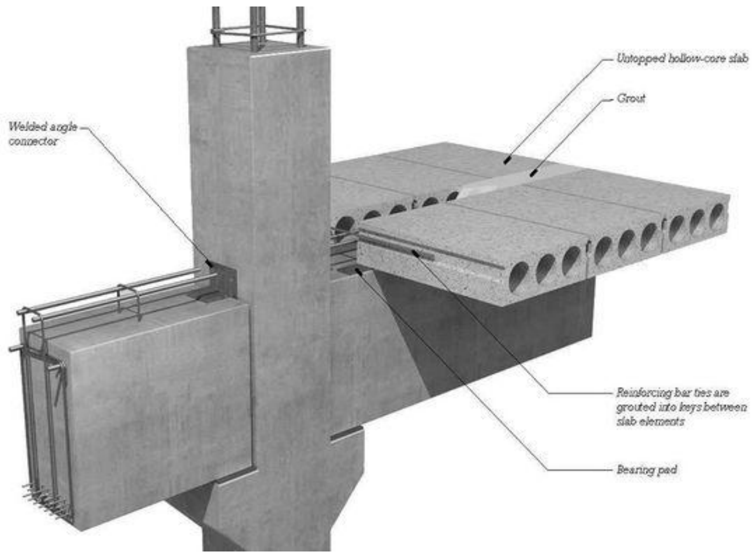

Figure 5.2 placement of beam on corbel

VI. CONCLUSIONS

Conclusions are drawn on the basis of literature reviews, it has been found that precast constructions has great potential to new market demands. Possible solution lies not only within the classical advantages related to working conditions, technology and speed of construction but also in new developments of materials such as high performance and self-compacting concrete, building system such as mixed structures, manufacturing technology, automation, service integrated products and others

6.1 Based on the investigations carried out on the responses of PRECAST buildings, the following conclusion are drawn.

1) Based on the research works, it is highly recommended to adopt precast concrete in building construction.
2) The building industry should consider the carbon reduction as a benefit of implementing precast concrete
3) Speedy construction is possible by precast concrete work so time factor gets optimised.
4) It is cheaper form of construction if large structures are to be constructed.
5) It becomes a solution to the problem of lack of local resources & labour .

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