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Review on Analysis and Design of Different Types of Prestress Concrete Composite Sections

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Abstract: Prestress concrete composite sections are highly versatile prestressed construction techniques as a result of it being an almost ideal combination of its two main constituents: high-strength steel, pre-stretched to allow its full strength to be easily realised; and modern concrete,pre-compressed to minimise cracking under tensile forces.It’s wide range of application is due to low self-weight and its high load carrying capacity, which fulfils the need of economic construction in most areas of structural and civil engineering.This literature reviews analysis and design of different types of prestress concrete composite sections.Composite prestress concrete sections consist of precast pre-stressed sections and cast in-situ concrete. Stiffness, cracking moment, Pretensioned and Post-tensioned technique. Tensile force is balanced by a compressive force applied at the centroid of equal magnitude. The force applied at the cast in situ slab causes a direct force acting at the centroid of the composite section together with a bending moment. The prestressed concrete composite units are erected first and can be used to support the formworkneeded for the cast in situ concrete slab (topping slab) without additionalscaffolding (or shoring) to obtain smooth and even floor finish. Erection of a topping slab on site resulted in improvements in the initial stiffness and cracking moment of Prestress composite sections. Prestress Concrete Composite Sections allows "load-balancing" forces to be introduced into the structure to counter in-service loadings and working loadings due to its Pretensioned and post-tensioned techniques according to its types:Pre-stressed ConcreteRectangularBeams,Pre-stressed ConcreteRectangular Slabs, Pre-stressed ConcreteI Girders& Pre-stressed Concrete Hollow Core Slabs.

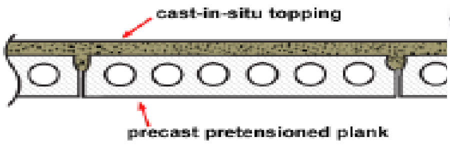
Keywords: Prestressconcrete, high-strength steel, low self-weight,Topping slab,shoring, initial Stiffness,cracking moment, Pretensioned and Post-tensioned technique.

I. INTRODUCTION

Prestressed concrete (PC) construction has obtained wide popularity in current constructions like buildings, bridges, dams, silos and tanks, etc. The resulting structure formed by prefabricated prestressed concrete sections and cast-in-place (CIP) concrete toppings is called Prestressed concrete composite sections. Prestressed composite sections has monolithic action between prefabricated units like prestressed beam, slab, girders and hollow core slabs with cast in situ concrete(toppings). This method is found to provide a greater structural efficiency compared with the conventional methods of construction. Toppings intended to have structural capacity should either be designed in accordance with recognised standards or have their likely performance independently verified. In a composite section, precast prestressed members are used in conjunction with the concrete cast in situ toppings, so that the members behave as monolithic unit under service loads. The composite action increases the load carrying capacity and stiffness of the beam by factors of up to 2 and 3.5 respectively. Prestress Concrete Composite Sections allows "load-balancing" forces to be introduced into the structure to counter in-service loadings and working loadings due to its Pretensioned and post-tensioned techniques according to its types: Pre-stressed Concrete Rectangular Beams, Pre-stressed Concrete Rectangular Slabs, Pre-stressed Concrete I Girders & Pre-stressed Concrete Hollow Core Slabs. Pre-tensioning is a common prefabrication technique, where the resulting concrete element is manufactured remotely from the final structure location and transported to site once cured & Post-tensioned concrete is a variant of prestressed concrete where the tendons are tensioned after the surrounding concrete structure has been cast. This technique is feasible & beneficial with structural point of view which gives many advantages in structural properties which provides longer spans for the same structural depth, Reduced structural thickness, Faster stripping time, Reduced material costs. This review paper focuses to study on deflection, flexural behaviour, load carrying capacity, ultimate moment capacity, shear behaviour and fatigue behaviour of different prestressed composite sections. Composite Sections implies the use, in a single structure acting as a unit, of different structural element casted with Prestressed concrete and cast-in-place (CIP) concrete toppings.Most prestressed concrete slab-on-girder bridges are simply supported with precast, pretensioned girders and a cast-in-place (CIP) deck. Spans are limited to about 150 ft due to weight and length restrictions on transporting the precast girder units from the prestressing plant to the bridge site. The precast concrete deck slabs were cast at a precast concrete plant and shipped to the bridge site where the cast-in-place concrete topping slab was placed and cured. Such bridge construction, while economical from an initial cost point-of-view, may become somewhat limiting whenlonger spans are needed. According to the available literature, a variety of methods have been used to extend the span range of concrete slab-on-girder bridges with cast-in-place (CIP) decks according to its dimensions.

Prestressed concrete hollow-core (HC) panels have been widely used throughout the world in concrete and steel structures. One of the most common use of these elements is in floor systems, where precast prestressed concrete hollow-core panels are used together with a cast-in-place (CIP) concrete topping to form a load-resisting composite floor system. The span of the HCS reaches equal (18m) without supports. Elements pre-stressed HCS purpose designed for various applications needing floor or roof systems. Manufacture of precast concrete hollow-core units mainly involves machine casting operation. These units are typically manufactured either by extrusion of really low-slump concrete, or slip-forming of a relatively higher slump concrete. The precast HCS has longitudinal voids extending the full slab length which makes the slab lighter than a considerable solid slab of equal depth or strength.

Prestressed concrete rectangular beams are widely used with CIP slab & concrete between joints as they improve the ability of material for energy absorption under impact load. Erection of a topping slab on site resulted in improvements in the initial stiffness and cracking moment of Prestress composite section. The in-situ concrete in a composite beam is of relatively low grade and has higher water cement ratio. On the other hand, the precast prestressed concrete is of higher grade and most of its shrinkage has already occurred before the placement of in-situ concrete. Tensile force is balanced by a compressive force applied at the centroid of equal magnitude at the time of fabrication to minimise cracking of in-service beams.



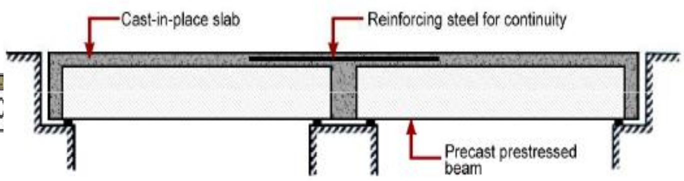
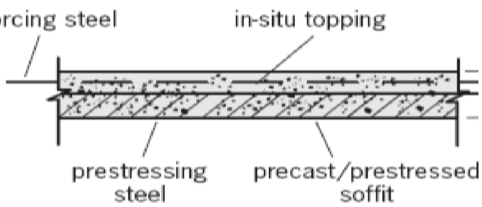


Fig. 1. Hollow-core slab with topping slab Fig. 2. Prestressed Concrete continuous beams with CIP slab (Praveen Kumar Shanmugam,2018) (Praveen Kumar Shanmugam,2018)



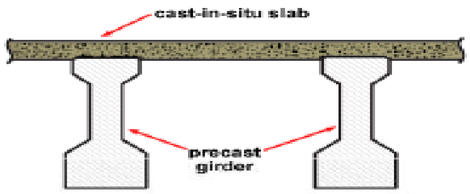


Fig.3. Prestressed slab with in-situ toppingFig.4.Prestressed Concrete I-section with topping slab (blogspot.com, February2010) (Praveen Kumar Shanmugam,2018)

Full-scale precast prestressed concrete rectangular slabs designed for various structures have been used widely & provided as various sections like bridge deck, prestressed concrete flooring having larger area has varying levels of roughness on the precast concrete slab and provided with cast-in-place concrete topping slab to make floor finished & smooth. Also, to increase the properties with composite action like ultimate moment carrying capacity, deflection, bending, flexure, shear capacity with precast prestressed sections by filling the joints with CIP toppings.

Prestressed concrete I-section are simply supported with precast, pretensioned girders and a cast-in-place (CIP) deck. Spans are limited to about 150 ft due to weight and length restrictions on transporting the precast girder units from the prestressing plant to the bridge site. The precast concrete deck slabs were cast at a precast concrete plant and shipped to the bridge site where the cast-in-place concrete topping slab was placed and cured. Such bridge construction, while economical from an initial cost point-of-view, may become somewhat limiting when longer spans are needed. A variety of methods have been used to extend the span range of concrete slab-on-girder bridges with cast-in-place (CIP) decks according to its dimensions.

Above prestress concrete composite sections as shown in above 5 figures are highly versatile prestressed construction techniques as a result of it being an almost ideal combination of its two main constituents: high-strength steel, pre-stretched to allow its full strength to be easily realised; and modern concrete, pre-compressed to minimise cracking under tensile forces. Erection of a topping slab on site resulted in improvements in the initial stiffness and cracking moment of Prestress composite sections.

A)TOPPING SLAB: - Concrete topping slab is an overlay designed to provide a dense, abrasion-resistant, and a finished floor surface for multiple purposes such as providing a wearing course to support traffic loads in parking facilities and bus terminals, providing a level surface for interior floors, providing special base for electrical and mechanical equipment, and to resurface worn or damaged floors. There are two major types of concrete topping slab namely bonded and unbonded toppings. Both are suitable for heavy duty and light duty concrete slab. The former generally includes residential, office, institutional, and light commercial uses. The latter, used typically in industrial buildings, is subjected to heavy moving and static loads, abrasion, and sometimes aggressive chemical attack. In some cases, concrete slabs are exposed to extremely hot or cold temperatures. Thickness of toppings is specified based on the expected loads and the variations in temperature a slab may have to go through. For bonded and unbonded concrete topping slab, strength of concrete for concrete topping slab is governed by function of the slab; 30MPa for light duty, 40 MPa for medium duty, and 50 MPa for heavy duty. The concrete topping used should have a maximum slump of 75 mm. If low w/c is employed, then a water-reducing admixture or high-range water reducing admixture should be used to increase the slump.

There are two methods to cast Cast-in-place concrete slab as follows: -
a) Unbonded Topping Slab
b) Bonded Topping Slab
a) UNBONDED TOPPING SLAB:

In this system, the topping slab is not bonded to the underlying concrete slab. The thickness of unbonded topping may influence final floor elevation and may interfere with other service requirements such as doorway clearances. If cracks in the base slab are repaired, they may eventually reflect through a partially bonded overlay. Reflective cracking can be reduced by using thicker overlays. It is used for contaminated slab for instance with oil, or for slabs with which bonding is not possible. Unbonded topping is also used when it is preferable to not bond the topping to the base course, so that the two courses can move independently, or so that the top courses can be more easily replaced at a later point of time. Joint spacing in the topping should be coordinated with joint spacing in the base slab. Additional joints should be considered if the topping slab thickness mandates a closer spacing than the base slab to limit uncontrolled cracking. For unbonded topping, the minimum thickness is 75 mm. Unbonded construction with a minimum thickness of 100mm is recommended if there are cracks in the base slab or if good bond is only partially attainable or totally lacking.

b)BONDED TOPPING SLAB:

In bonded system, the topping is adhered to the underlying concrete slab. It is used for both light duty slab in commercial applications and heavy-duty slabs in industrial applications subjected to heavy traffic loads and impact. The surface of the base slab should have a rough, open pore finish and be free of any substances that would interfere with the bond of the topping to the base slab. The topping can be placed before hardening base concrete slab, or after the base slab has hardened. Bonded topping minimum thickness is 19 mm and not more than 50mm.

B) STAGES IN CONSTRUCTION OF TOPPING SLAB: -

- Prepare concrete slab surface if it is an existing surface. This stage is not needed if the topping is placed just after the construction of slab base.
- Fix forms.
- Place insulation in the case of unbonded topping such as plastic sheet.
- Apply adhesive agent to concrete surface in case of bonded topping. This process sometimes becomes optional since roughness and pores of concrete surface may be adequate to generate enough bond strength between slab and the topping.
- Install reinforcements
- Pour concrete
- Finish concrete surface using suitable means based on the type of topping and materials used.
- Apply suitable curing methods.

II. LITERATURE REVIEW

Eray Baran(2015): -This literature performed by Eray Baran focuses on flexural response of precast prestressed concrete hollow-core slabswith cast-in-place concrete topping under flexural loading. In this literature experiment performed on five precast concrete hollow-core units & the study includes load testing. According to the paper, to ensure a proper bond between the CIP concrete topping and the precast hollow-core panels, the surface of the panels must be clean, free of laitance, and thoroughly saturated prior to casting of topping concrete. The specimens were divided into W and N. The design concrete compressive strength for the tested hollow-core units was specified as 30 MPa but no information was available regarding the measured compressive strength of concrete and stress in strands. The specimens were tested under monotonically increasing displacement loading until failure occurred. Two displacement transducers were used to measure the vertical deflection as well as, the relative slip between the hollow-core unit and the topping. This literature aims towards study of understanding the behaviour of composite hollow-core units under flexural loading by using concrete topping by comparing flexural response with experimentally obtained behaviour. Restraint mechanism was used at ends of Specimens was only used as a method to see the case of fully composite behaviour & improves the horizontal shear force transfer between hollow-core unit and topping slab. The flexural cracking on hollow-core units was observed to occur at midspan section directly below the applied load. The different types of cracks observed under gradually applied loading & Crushing of concrete at the top of hollow-core unit near the midspan section was also evident. For both series specimens, existence of a topping slab increased the cracking moment and initial stiffness. The increase in cracking moment was 22% and 33%, while for stiffness was 93% and 118% for the W and N series specimens respectively. Existence of topping slab increased the ultimate moment capacity by 23% and 13% for wide and narrow specimen respectively. Variation of maximum horizontal slip of 1.38 cm and 0.71 cm between the hollow-core unit and the topping slab. As a result, a composite behaviour was valid throughout the load testing for Restrained mechanism. Based on three pushoff tests, the average interface shear strength was determined to be 0.19 MPa while computed shear strength values were between 0.20 and 0.23 MPa which is lower than specified by the ACI and AASHTO Specifications due to relatively smooth surface of hollow- core units.

Norman L. Scott (1973):-According to this paper, observed ultimate moment was about 10 percent greater than calculations based on Eq. (18-3) in ACI 318-71 of machine-made hollow-core slab with composite topping verified a number of accepted industry design by using load test. Scott tested a hollow-core slab unit with a CIP concrete topping and the agreement between the calculated and measured moment capacity and deflection values suggested a full composite action between the hollow-core unit and the topping. The concrete impact hammer method used to determine compressive strength in machine-made slabs. Therefore, hammer test was performed on machine casted by taking an average of 8 readings of slab and 11 readings of toppingwhich indicates lowercompressive strengths than actual on the side of the floor. From this study on precast concrete hollow-core units, the specimen in Scott's study was tested by placing solid concrete blocks on top of the composite slab.After five stage load testing, deflection was checked after each layer of block was placed on the slab. The test describes deflection at different stages and shows failure within these five-stage load test. It specifies deflection at first 2 stages, flexure cracking in next two stages and in last stage the failure was gradual and was the result of yielding of the prestressing strands. Ultimate Moment calculated using two methods prescribed by ACI 318-71. The first calculations, based on Eq. (18-3) for fr, & the second calculation, based on strain compatibility making use of the design aid in the PCI Design Handbook (Fig. 5.2.5). The results show that the ultimate flexural capacity of prestressed members can be predicted very precisely using the provisions of the ACI Building Code. Also, the slab tested for flexural failure. This test also demonstrated the shear strength capabilities for this member with a concrete topping of modest strength. Therefore, Calculations using strain compatibility method ultimate moment matches the observed ultimate moment. Also, deflection calculated using the bilinear moment deflection relation is 4.85 in. matches the observed deflection of 4.97 in. approx. Therefore, the bilinear method is very close at this stress level.

Fangzhou Liu, Jean-Marc Battin, Costin Pacoste, Alexandra Granberg (2017): -This shows the work on experimental tests and numerical analyses are performed to understand the dynamic behaviour of hollow core concrete floors to develop finite element model with different geometrics, boundary conditions and thicknesses. Due to low self-weight and longer span the vibrations and induced due to human activity. This paper does not represent natural frequency and associate mode shapes of floor which are identified using dynamic experimental tests. This experiment performs a test on six units of test floor with 50mm height of concrete topping on the slab 30 days after the casting of the joints. The objective of authors to determine highest and lowest natural frequencies, damping coefficients & mode shapes. This test had been conducted using two methods i.e. with a hammer and vibrator exciter. The horizontal and vertical accelerations were observed by using 10 nos. by using SF1500 accelerometer using sinusoidal force generated by harmonic force system and magnetic vibrator extractor with peak force of 25 N and 112 N respectively to generate accelerations corresponds to human induced vibrations. The second loading was an impact force performed by heavy duty impact hammer forming an impulse load & gives frequency up to 50 Hz. By Using Abaqus 6.14different models had been developed for hollow core unit & Topping with the steel part. From results obtained error comparison between numerical and experimental natural frequencies and mode shapes was extracted by modal superposition was used for steady state analysis. Processed using MATLAB, the damping ratios and maximum natural frequency had been calculated under half band width method in three phases using vibrator exiter method and impact force hammer. The four modes were observed bending, torsional, bending along lateral direction & along both directions with the parametric study the multiplicative factor of elastic modulus of concrete 1.05 for hollow core element ,0.55 for joints & 0.8 for toppings had been observed. The differential shrinkage between hollow core slab and topping were also observed. Very good agreements between experimental and numerical results had been observed. This finite element models have been used to implement for different sizes of slabs to find natural frequency & to calculate response to impulse loads.

A. M. OZELL (1957): -In this paper, elastic and ultimate behaviour of simple and continuous composite prestressed concrete beams constructed by placing two simply supported prestressed beams end-to-end and by providing mild steel in the negative moment zone had been examine. It determines the cracking loads, ultimate loads, strain distributions, deflections, measuring of reactions & preliminary beam test to determine effect of sheathing on continuous composite beams. Test performed with three different cross-sections. All simply supported beams except two beams was tested with Riehle screw-power, beam balance, testing machine with a single concentrated load & hydraulic jack was used. Loads was applied on each beam with increment in load determines cracking load, concrete strains & deflection. Cracking load was drawn by 3 methods:observation of the beam for any visible cracks; by detecting an appreciable increase in the strains & by observing a sharp break in the load deflection curve gives the stresses at cracking by performing calculations.The Concrete strains distribution had been measured and obtained the strain results using sheathing as per the type of beam and deflections were measured with Ames dials reading to the nearest .001 in for both types. Observed values for stress versus strain curves from which the initial tangent modulus of elasticity of the concrete was obtained using automatic recording device. The results observed the measured strain distribution indicated composite behaviour of both types using topping. By determining percentage of continuity by using load-deflection method gives the load versus deflection curve for simple continuous beam to find the value of EI for all three types of beam. As a result, for longer spans the percentage of continuity could be greater since larger values of negative moment result from greater span lengths. The behaviour at ultimate load, Cracks was observed at different places on beam surface according to its applied loading within three group results Superimposed load versus measured-strain relationships in the negative steel of various beams. Observed percent continuity determined by the method of measured reactions is more accurate than by the method of load deflections. Effect of composite greatly increased the carrying capacity of all three types of beams tested.

John J. Roller, Barney T. Martin, Henry G. Russell, Robert N. Bruce, Jr. (1993): -This paper performs a design and analytical test on bulb-tee girder with and without deck slab to evaluate flexure and shear strength & to determine in-service long-term behaviour under full design dead load by utilizing high strength concrete for bridge girders. Results of this experimental evaluation indicate that use of high strength concrete for prestressed bridge girders is both feasible and beneficial. This paper describes the details and results of the girder tests conducted testing on high strength concrete bridge bulb-tee girders. About two Girders had been tested for flexure and shear with and without deck slab. The design of girders had been done as per the AASHTO standards. Design of girders results the average compressive strength of three girders was 63.6 MPa were observed. Girder 3 was simply supported and subjected to a constant load approximating the in-service design dead load for a duration of 18 months to perform long term test. After design it was transported and deck slab had been casted using partially shored construction. The girders have been instrumented to measure concrete strains, camber and prestress losses and whittemore gauge had been used to determine transfer length, to provide an indication of concrete strains & measurement of concrete surface strains respectively. The material properties were adopted as per ASTM & AASHTO Standard Specifications for Highway Bridges for Girder Concrete, Prestressing Strand & Deck Slab Concrete. The design results in Material Properties, Transfer Length, Prestress Losses & Girder Camber is obtained using the AASHTO standards. The flexure and shear test were performed on the two girders using ‘hydraulic jacks’ results in cracks gives cracking moment by using calculations. It observes measured concrete modulus of elasticity for the three girders correlated with values calculated using AASHTO. Transfer lengths examines from concrete surface strain measurements was better as expected. Concrete strains have been measured at a concrete age of 28 days indicated that prestress losses were significantly less than the losses & also, Study gives measured flexural and shear properties met or exceeded values calculated using provisions from the AASHTO Standards and measured material properties and prestressed losses. Data observed for the deck slab concrete surface (concrete topping) strain gauges indicated that the full width of the deck slab was effective throughout the flexural test. Long-term test of Girder 3 had been completed in September 1993.

Henry G. Russell, John J. Roller, Robert N. Bruce, Jr., Barney T. Martin (1995): -This paper performs a test on bulb-tee girder by performing design with deck slab to evaluate flexural properties using long-term static loading test and fatigue performance using fatigue loading testusing current AASHTO provisions. Results of this experimental evaluation indicate that use of high strength concrete for prestressed bridge girders is both feasible and beneficial. This paper describes the details and results of the girder tests conducted testing on concrete bridge bulb-tee girders.Early-age flexural properties and long-term behaviour was determined using in-service design dead load and 5 million cycles of fatigue loading to evaluate the fatigue performance of the girder. The design of girders had been done as per the AASHTO standards to perform different test. The long-termstatic loadtestwas performed using additional dead load to produce a series of four concentrated loads & monitor the behaviour of Girder 3 under full design dead load for a period of 18 months with measurement ofinternal concrete strains, camberand prestress losses. The actual measured prestress loss in Girder 3 at 18 months was approximately 50 percent less than the expected value. Six stages required to perform Fatigue load test girder 4 which was subjected to cyclic flexural loading with gradually increasing loading with frequency of two cycles/second gives load-deflection relationship. The material properties were adopted as per ASTM & AASHTO standard for Girder Concrete, prestressing Strand & Deck Slab Concrete. The decompression load was determined based on data from the concrete surface strain gauges and the crack width gauges. After performing both test flexural test was performed by applied loading using hydraulic jacks. All girder was tested to determine flexural cracking moment and ultimate moment capacity (failure). Results had been observed that a single girder withstood 5 million cycles of fatigue loading without any significant increase in prestress loss or cracking in the girder concrete andboth of two still fulfilled the strengthand serviceability requirements of theAASHTO Standard after long-term static load and the fatigue load test. Results gives full width of deck slab was more effective suggested by AASHTO Standards.

III. ADVANTAGESOF PRESTRESSED CONCRETE COMPOSITE SECTIONS

- PSC sections with topping slab are more durable since there are no tensile cracks and higher tensile strength hence there is no danger of adverse environmental effects whereas in RCC tensile cracks are unavoidable.
- As high strength concrete is used dead weight of PSC unit is much less compared to RCC unit. The dead weight of PSC sections is about one-third of equivalent RCC sections.
- The deformation of PSC member is much less due to high loading carrying capacity. In case of beams deflection of PSC beams is about one - Fourth of that of equivalent R.C. beams.
- The fatigue strength of PSC is very good.
- It reduces construction cost and time as the prestressed unit is prefabricated & the cast in situ concrete slab does not need to have high mechanical properties and they are suitable to any field conditions.
- The prestressed concrete element is factory-produced and contains the high tensile reinforcement, rigorous quality control and higher mechanical properties can be achieved at relatively low cost with Cast in place concrete slab.
- Savings in form work as Cast-In-Place concrete does not requires formwork because precast prestressed section support the topping slab as formwork.
- Fast-track construction.
- Easy to connect the members and achieve continuity between prestressed sections using CIP concrete slab which increases diaphragm action.
- Compared to In-situ concrete, prestressed composite sections erection is faster and less affected by adverse weather conditions and with easily casting of topping slabs.
- After the CIP slab with filled Section joints, the members get the finished and smooth surface with accuracy.
- The precast prestressed sections have been erected using steel moulds with exact dimensions several times due to their durability property and erection of CIP slab gives feasibility and benefits.

IV. LIMITATIONS OF PRESTRESSED CONCRETE COMPOSITE SECTIONS

- Availability of experienced builder's is scanty
- It requires skilled labour and good quality control.
- Prestressed Sections needs special technique to apply prestressing forces and Anchorage the wires.
- Initial equipment of cost is high.
- Prestressed Sections are brittle require proper handling.
- It requires high tensile steel, which is 2-3 times costlier than mild steel.

V. CONCLUSIONS

On the basis of above research papers conclusions has drawn, it has been found that prestressed composite sections with CIP concrete toppings has great demands to new structural constructions as they are feasible and beneficial with less time consuming. Based on the reviews the conclusions are carried out on the different types of Prestressed concrete composite sections with Cast-in-place concrete toppings: -

- Above research papers conclude that prestress concrete composite sections are very important and needed prestressed construction techniques in major constructions as it's wide range of applications is due to low self-weight and its high load carrying capacity, which fulfils the need of economical and rapid construction.
- Due to natural concept of prestressing structure when the prestressed force applied to any prestressed section it hogs up to some extent and it is undesirable to use it in that form. For this purpose, CIP concrete toppings are placed over such sections and a new combine section emerges, which we called as composite

prestressed sections. This newly combined section is ready to use because of its levelled surface. For e.g. Prestressed Composite slab, beams, floors, etc.

- The behaviour of the individual beams with Cast-in-place concrete topping followed the elastic theory very closely until cracking and for continuous beam the percent continuity of this type of construction determined by the method of measured reactions is believed to be more accurate than by the method of load deflections.
- It is highly recommended to adopt Prestressed concrete composite sections in building construction, bridges, flooring, etc to optimize the construction time and also, they are cost effective.
- For HCS conclusion has drawn that existence of topping slab resulted in increased percentage of cracking moment, initial stiffness, and ultimate moment capacity of wide bare hollow-core unit.
- High strength concrete for CIP concrete toppings is more viable and economically beneficial alternative for future highway bridge projects for its high structural properties.

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