Review Article

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Analysis of Reinforced Concrete Structures by Using Concrete with Heterogeneous Grade with Pre-Fabricated Structural Steel

Rohan S Shreshthi[1]* and Anilkumar Gupta[2]

[1]Assistant Professor, Department of Civil Engineering, Dr D Y Patil College of Engineering and Technology, India

[2]Department of Civil Engineering, Executive Director, Dr D Y Patil Group, India

[*]Corresponding Author
Rohan S Shreshthi, Assistant Professor, Department of Civil Engineering, Dr D Y Patil College of Engineering and Technology, India.

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Abstract
The purpose of this article is to review the beams made up of reinforced concrete which is added or prepared with by inclusion of Fabrication material in the form of structural steel which can be known as Pre-fabrication steel material. However, here beams were analysed under construction with a pre-fabrication steel cage, and the flexural tests. For columns, the prefabrication columns showed the results in a very positive manner in terms of time and economy. As per the results investigated for columns with pre-fabricated, time was saved by nearly 33.3 % and cost was saved by nearly 7.1% for each. Results were analysed by comparing with a moment of resistance by experimental ultimate moments and theoretical design moments. This method used was an alternative to rebar specimens & had achieved positive strength with very economical sections. Studies regarding dual-grade concrete or both different concrete grades for beams in Plain cement concrete and reinforced concrete reported that low-grade concrete is placed near the neutral axis zone of the beams and flexural behavior of the beams was carried out. Usually, two zones appear: a tension zone at the bottom and a compression zone at the top. Steel is added to the tension zone to absorb the tension caused by the weakening of concrete, however, the strength of the concrete is disregarded in the tension zone relative to the compression zone. The depth of higher-grade concrete increases in the compression zone, and resistance to first crack development also increases.

Keywords: Pre-Fabricated Structural Steel, RCC Structural Elements, Flexural Strength, Strength Efficiency

1. Introduction

A typical material used to construct a variety of constructions, including parking garages, high-rise buildings, bridges, and buildings, is reinforced concrete (RC). Together, high tensile strength steel and high compression strength concrete provide a mechanism to withstand applied loads [1]. In the building industry, cold-rolled steel sheeting is now frequently utilized as a form of reinforcement. One example of composite steel and concrete structural components, sometimes referred to as composite sections, is the use of permanent and integral shuttering composed of cold rolled sheets as form and reinforcement in the building of composite slabs [2]. Composite section shapes varied according to the designer's ideas. By encasing the concrete element in steel or by encasing the concrete between two skins of steel, such composite sections can be created from hot-rolled steel sections [2]. A novel concept for beams made of hollow steel components with a concrete infill is the steel-concrete composite section, which can be used in small- to medium-sized buildings in place of hot-rolled steel or reinforced concrete [3]. The following is a summary of the structural benefits of composite construction over non-composite construction: The steel beam's depth is decreased to accommodate specific loads. A building's overall cost can be decreased by reducing dead loads and construction depth for a given load, which also lowers story heights, foundation costs, exterior panels, and the cost of heating, ventilation, and air conditioning systems [1].

The use of PCS in reinforced concrete structures reduces overall construction costs and expedites the construction timetable. Construction contractors as well as private owners or the federal government should take note of this. Researchers might also be interested in the engineering economics techniques this paper presents [4]. the flexural strength and ductility of a reinforced concrete beam must be considered during design. Ductility is just as crucial as strength. When a beam has good ductility, it will have a considerably higher chance of surviving overloading, unintentional impacts, and strong seismic attacks [4]. A popular building method with shown benefits of higher ultimate strength and stiffness is the composite concrete slab on steel beam [5]. Steel reinforcement is positioned at the bottom side of the beam section to withstand tension, as concrete is not strong in this area. The compressive strength of the concrete lying above the neutral axis is a crucial characteristic because compressive stresses are generated in the zone above the neutral axis [6].

1.1. Overview of Literature Review

This present review paper is based on the work performed in the past nearly decade+ 6 years of research in the field of steel and concrete. Identification of the core material in the construction sector which deals with analysing the efficiency of the structural element, the strength of material adopted, economic feasibility for making of component, and behavioural response of structural element pre and post-testing.

1.2. Pre-Fabricated Structural Steel

The prefabricated construction system relies on the extent to which prefabricated components are utilized, their materials, sizes and the strategy took on for their production and use in building. The part of the way or partly or fully i.e., completely gathered and raised working, of which the underlying parts comprise of pre-assembled individual units or assemblies made with materials that are controlled or common, counting administration offices; and in which the help hardware might be either pre-assembled or developed in-situ [7]. The term "Prefab" is employed as a reference to prefabricated buildings. Abbreviation for buildings that are constructed off-site and then transported to their location for assembly, which includes various kinds of structures. In technical terms, any house that includes segments of the framework constructed in a factory and subsequently put together on-site the location can be classified as a "prefab" site. A light steel frame is used to construct a prefab house.to use sandwich panels for the exterior of the building materials used as a typical component in space-related collection coming together of parts, the fastening with bolts, and the fresh idea of conserving the environment economic operations in prebuilt housing. Constructing the standard and conventional structures requires a significantly longer time. The price is equally expensive. there will be an increase in the environment being contaminated with waste; workers will also be affected traditional buildings are also unsafe during construction. If there are numerous issues in adhering to the requirements of traditional patterns, we should seek out the familiar trend. The most convenient and efficient method for construction work. Need to work together in order to achieve our goals must adhere to the latest methods, namely pre-fabricated. structures made of steel that are modular in design. The process of constructing in this manner structures will reduce the cost &time of construction and unrelated squanders. However, it enhances the standard & beauty of the structure and the Work's efficiency [8].

1.3. Cage Pre-Fabricated Steel

R Chithra & R Thenmozhi, Studied the behaviour of composite beams which were made with a steel case that is pre-fabricated [2]. They estimated the flexural strength of the beam and compared the results with theoretical analysis. Failure manifests itself in the pure bending zone. In this research, the impacts of concrete have been examined. the influence of strength &confinement on the flexural ductility of PCRC beams was assessed and the ductility factor as a parameter indicated how well a material can deform before breaking structural elements to bend out of shape. As they reviewed the research of M Shamsai et al [1,9].

The cage system resulted in a 33.3%-time savings and a 7.1% cost savings over rebar for each column. This resulted in an average of 3.6% savings on total project cost; an average of 22.2% savings on total column costs; 20.4% savings on the total project time period, &33.3% savings on the column construction time period. M Shamsai et.al has evaluated the technique which can be an alternative to conventional reinforcement [1]. They created a cage of Steel structure which is pre-fabricated and used in replacement of conventional steel for beams and columns. They found the PCS provided results in terms of time and cost were very efficient and effective. They achieve approximately 33.3% savings in time and 7.1 % savings in cost as compared to traditional rebar for every column.

H Sezen have tested 15 column specimens made up of pre-fabrication steel. As they reviewed the research M Shamsai et al [1,10]. The behavior is tested and compared with similar reinforced concrete columns. They are tested against compression load for which they found the results were very superior for Prefabricated Cage steel column specimens as compared to conventional reinforced columns. The PCS specimens had larger residual strength and deformation capacity. The effect of steel plate thickness on the strength and deformation capacity was not significant; however, PCS reinforcement with very thin plate thickness resulted in a slightly smaller maximum strength. Provided that the steel amount was the same, the no of longitudinal strips or bars & the transverse reinforcement spacing did not have a significant effect on the behaviour of the specimens. A new model was proposed for concrete confined by PCS reinforcement. M Shamsai & H Sezen, have analysed 16 no columns made up of pre-fabrication [11]. They have compared the results with the column made up of conventional method i.e., by using reinforcement. They have found that PCS has the potential to enhance structural performance. enhanced physical connection between reinforcement and concrete. PCS has the ability to create specific transfer opportunities. The study looks at how PCS columns behave in comparison to rebar-reinforced columns, considering different factors like steel tube thickness, amount of longitudinal reinforcement, spacing of transverse reinforcement, and presence of crossties.

P Paudel et al, have constructed a house with structural steel members [8]. Switching from a light steel frame to sandwich panels for the construction of the building. materials used for space module envelopes combination of components in a series, the bolt link, and the innovative idea of ecological connections safeguarding economic operations within prebuilt homes. the preassembled parts are delivered to the location. constructed using blocks for building purposes.

1.4. Structural Member with Double Grade Concrete

Kim Chul-Goo et al., has investigated the beam with two different concrete grades with respect to the beam depth [12]. They have cast the same beam with two different methods. They adopted the Pre-cast method at some specific depth and the remaining part with cast-in-place method concreting. Likewise, they tested 20 simple beams for shear strength using double-grade of concrete. They have adopted M60 as High strength concrete and M24 as Low Strength Concrete. They have analysed the two different zones of beam depth around the Neutral Axis i.e., compression zone and tension zone. As S B Kandekar has examined the zones of beam depth concrete is good in the compression zone and steel is good in the tension zone about neutral axis depth [6]. Due to this, the beam below, the neutral axis is filled with low-grade concrete, and continuing with that beam above the neutral axis is filled with higher-grade concrete. This led to a reduction of cost per beam and that provided the results in a very efficient manner after testing for flexural strength. Togay Ozbakkaloglu investigated the structural member by using fiber-reinforced polymer for concrete steel composite column section [13]. Here, the column is made up in tabular form in which the same specimen is filled with concrete having two different grades. The tubular column specimen was executed as normal-strength concrete filled in an annular section of the column while the inner or core part of the steel tube column was packed with a superior-quality concrete mixture. R Dhanaraj et al., have studied the content of steel fiber, basalt fiber, and coir fiber where cement is partially replaced by 10% of silica fume [14]. They prepared the mix proportion for two different grades of concrete M40 and M50. They found that the use of fibres in elements increases tensile strength. Paul Mathews and Kuriakose Anuja have investigated the plain cement concrete beams by using low-grade concrete about neutral axis zone and flexural behaviour has been studied [15]. Where here standard properties of cement were studied and the physical properties of fine aggregate and coarse aggregate were taken.

2. Conclusion and Discussion

This paper reviews about the strength achieved by structural members with pre-fabricated steel which has been adopted in the replacement of conventional steel reinforcement. R Chithra and R Thenmozhi, have tested for flexural strength and behaviour of their specimen with pre-fabricated steel with concrete under a 100T capacity frame [2].

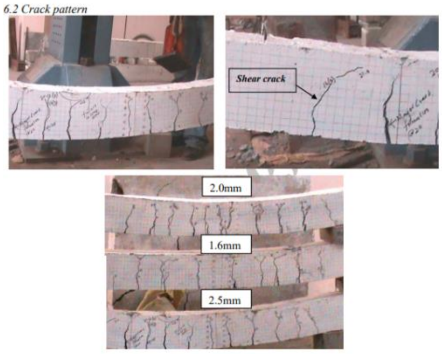

Figure 1: Photograph Showing the Crack Pattern for PCS Beams [2]

The above figure symbolizes the crack pattern developing nearly up to 40 % to 80 % of loading as increases. Initially, it was found that hairline cracks develop at 40% load then further as the load increases up to 80% cracks develop at the shear region [2]. To look into the flexural behavior of PCS beams, nine full-scale specimens in three different thicknesses were cast and put through pure bending tests. A thorough analysis was done on the crack pattern, load-deflection curve, and ultimate strength. Given that the beams were beneath reinforced, in a pure bending zone, the tensile reinforcement yielded prior to the concrete's crushing [2]. PCRC beams suggest true ductility behavior.

Beam id	Deflection at yield load Δ_y mm	Deflection at ultimate load Δ_u mm	Displacement ductility factor $\mu_\Delta = \Delta_u / \Delta_y$	Span/ Δ_y
A	3.75	48.2	12.85	555
B	5	61.35	12.27	416
C	5.9	62.09	10.52	353
D	4.3	60	13.95	484
E	7.2	61.24	8.51	289
F	9	57.8	6.42	231
G	4.6	64.2	13.96	452
H	7.2	62.35	8.66	289
I	9.32	58.5	5.52	223

Table 1: Deflection of PCRC Beams and Displacement Ductility Factors [2]

They determined that all the specimens display properly put-up yield behavior with appropriate ductility overall performance because of confined compressive area. Mohammad Shamsai et.al have found that the overall behavior of all specimens becomes very similar [10]. A representative axial load-displacement relation consisting of important Stages. Usually, the specimens behaved elastically without cracking until the height strength or maximum strength was reached.

Figure 2: Stages of Crack Development; cover spalling; longitudinal steel buckling and transverse steel fracture; and final failure of the Specimen [10].

The cracking normally started suddenly close to the corners both at the top or bottom of the specimen. After the peak strength was reached, a small drop within the energy became located [10]. M Shamsai and H Sezen have investigated 16 small-scale column specimens for axial displacement [11]. In that, nearly 11 PCS reinforced concrete columns with an average 28-day measured compressive strength of 33.4 MPa. Comparable rebar specimens were not as energy-absorbing as PCS-reinforced specimens, which exhibited smaller residual strength and greater displacement ductility.

No.	Specimen name	Absorbed energy, E (kN mm)	Ductility, μ	$\frac{\mu}{\mu_{rebar}}$	$\frac{E}{E_{rebar}}$
1	12P3/16	31871	10.66	1.78	1.91
2	8P1/4	35165	11.65	1.53	1.78
3	8P3/16	29056	12.81	1.68	1.47
4	8P1/8	23055	11.35	1.49	1.17
5	4P1/4	48912	28.04	2.57	2.28
6	4P3/16	36610	17.56	1.61	1.71
7	8P3/16DS	32510	5.86	0.69	1.79
8	8P1/8DS	24201	4.72	0.56	1.33
9	12P3/16CT	44827	16.95	1.61	2.24
10	8P3/16DSCT	40790	12.85	1.22	2.04
11	8P1/8DSCT	39752	12.81	1.22	1.99
12	12R	16650	6.00	1.00	1.00
13	8R	19744	7.61	1.00	1.00
14	4R	21452	10.93	1.00	1.00
15	8RDS	18182	8.48	1.00	1.00
16	8RDSCT	20007	10.54	1.00	1.00

Table 2: Displacement Ductility and Absorbed Energy for Test Specimens [11]

It was determined that the presence of crossties enhances concrete confinement, column strength, and displacement capacity by preventing PCS steel from buckling [11]. The behaviour of equivalent rebar-reinforced columns and PCS-reinforced specimens was compared. They found that comparable rebar specimens were not as energy-absorbing as PCS-reinforced specimens, which exhibited smaller residual strength and greater displacement ductility [11]. A Soundararajan and K Shanmugasundaram have estimated the behaviour of simply supported beams having long steel hollow sections filled in different cases

a) Normal Strength Concrete
b) Fly Ash
c) Quarry Waste
d) Low-strength concrete [3].

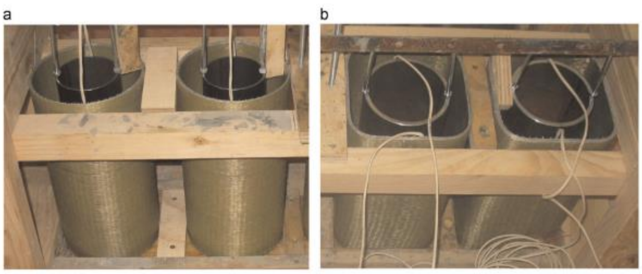

Figure 3: Testing Arrangement of Beam Specimen [3]

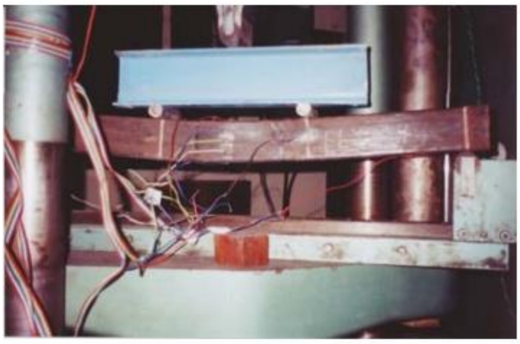

Figure 4: Beam Under Testing

These results of the experimental studies showed that ordinary mixing, fly ash, mine tailings, and low-strength concrete increase the carrying capacity of open steel sections. In addition, it can be seen in these studies that common mix, fly ash, and mine waste concrete can be used in composite construction to increase the bending strength of steel hollow sections [3]. According to A Soundararajan and K. Shanmugasundaram research, they concluded that the beams containing regular concrete mix, fly ash concrete, quarry waste concrete, and low-strength concrete showed the ability to achieve the complete flexural strength of their sections [3]. Furthermore, regular concrete mix, fly ash concrete, quarry waste, and low-strength concrete improved the ultimate moment capacity of the steel hollow sections.

AKH Kwan, et al., has evaluated the correlation between flexural strength and flexural ductility for reinforced concrete beams [4]. The concrete grade, tension steel ratio, and compression steel ratio significantly influence the flexural strength and ductility of a reinforced concrete beam section.

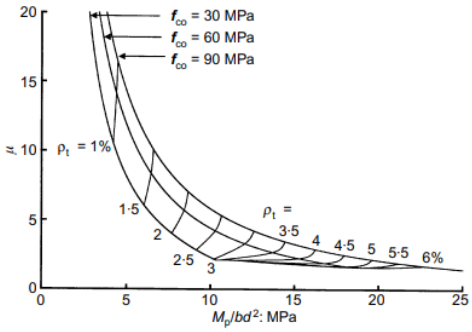

Figure 5: Flexural Ductility Plotted Against Flexural Strength for Each Concrete Grade [4]

Adding compression reinforcement instead of increasing the tension reinforcement could enhance flexural ductility substantially while improving flexural strength only marginally. The combined addition of compression and tension reinforcement enhances both flexural strength and ductility [4]. David Leaf and Jeffrey A Lama, have estimated the ultimate flexural strength of the composite beams is determined through laboratory testing and analysis, utilizing current methods, and is contrasted with their actual performance [5]. Composite steel-concrete beams fail prior to reaching their predicted nominal flexural strength based on AISC testing results. As we saw earlier in this paper Togay Ozbakkaloglu investigated the compressive behaviour of the FRP-concrete-steel composite column system with two different grades of concrete in one structural section [13].

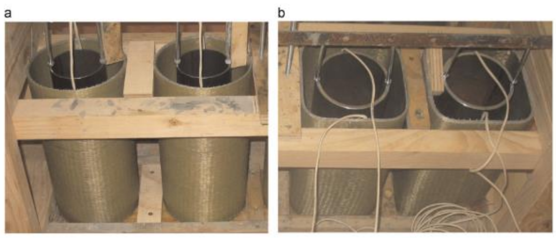

Figure 6: Fabrication of Specimens (a) Circular DSTCs and (b) Square DSTCs (Double Skin Tabular Columns) [13]

The annular gap between the FRP and steel tubes is filled with normal-strength concrete, while the core of the steel tube houses a higher-grade concrete mix. Circular and square DGC DSTCs display remarkably superior axial load and deformation capabilities, leading to increased system, and concrete ductility [13].

Knowledge Gaps in Research for Future Work Scope

From the current review of the literature, the following knowledge gaps have been detected.

1. The Flexural Strength of RC Beam is calculated in the literature served but the dimensional analysis is ignored.
2. The combination of Pre-fabricated structural steel with a combination of
3. Concrete having two different grades in one single structural element in the beam is not found in literature, which can be more crucial in economic saving and structural stability.
4. Analysis of graph showing different column sizes to strength which is not estimated in current literature, can be estimated in future work with Prefab and double concrete grade symbolizing the reduction of column size which provides desired load carrying capacity with balanced economy estimation.
5. A comparison of Lower strength, Normal strength, and higher strength concrete is missing in any of the literature but can be done to get the superior combination for On-site construction in Residential Buildings, Commercial Buildings, and bungalow sites that come under earthquake zone II [16-18].

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