A Review Study On Cold-Formed-Ferrocement Composites

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Abstract: The objective of this study is to provide a review on cold-formed-ferrocement composites. This study is not reported in literature. Therefore, all the literatures cited herein are based on researches carried out on ferrocement-concrete and cold-formed-concrete compositely. However, the use of cementitious composites for infrastructure applications is becoming more popular with the introduction of new high performance and lightweight materials. Ferrocement laminates are introduced to enhance overall performance of structures that are constructed compositely such as beams, slabs, columns, load bearing walls, bridge decks etc. The results has shown that the composite specimens studied were promising and possess good flexural and impact strengths, ultimate capacity, retrofitting capability, reduced crack width, fire resistance, insulation resistance, energy absorption, ductility, pull-out resistance, shear resistance etc. Moreover, cold-formed-ferrocement composites have the capability and high tendency of improving performances of structures to be constructed compositely and will improve corrosion prevention etc. Therefore, it is highly recommended that investigations using cold-formed-ferrocement composite is an essential research.

Key words: Cold-Formed steel, Ferrocement, Composites, Wire Mesh, Beams, Slabs.

INTRODUCTION

The use of cold-formed steel members in building construction began in the 1850s (Yu, 1999; Allen, 2006) in both the U.S. and Great Britain. However, such steel members were not widely used in buildings in the U.S. until the 1940s. At the present time, cold-formed steel members are widely used as construction materials worldwide. Compared with other materials such as timber and concrete, cold-formed steel members can offer the following advantages: (1) lightness, (2) high strength and stiffness, (3) ease of prefabrication and mass production, (4) fast and easy erection and installation, and (5) economy in transportation and handling, just to name a few (Yu, 1999). According to Yu (2000), since 1946 the use and the development of thin-walled cold-formed steel construction in the United States have been accelerated by the issuance of various editions of the “Specification for the Design of Cold-Formed Steel Structural Members” of the American Iron and Steel Institute (AISI).

Cold-Formed Steel members are widely used in building construction, bridge construction, storage racks, highway products, drainage facilities, grain bins, transmission towers, car bodies, railway coaches, and various types of equipment (Yu, 1999; Yu, 2000). These sections are cold-formed from carbon or low alloy steel sheet, strip, plate, or flat bar in cold-rolling machines or by press brake or bending brake operations. The thicknesses of such members usually range from 0.0149 in. (0.378 mm) to about 1/4 in. (6.35 mm) eventhough steel plates and bars as thick as 1 in. (25.4 mm) canbe cold-formed into structural shapes (Yu, 1999; Yu, 2000). In recent years, the application of steel structure housing has been widespread in China, compared with the traditional concrete structures and brickwork structures (Zhang, et al., 2013). Cold-Formed Steel (CFS) is widely used in conventional construction as well as in metal building systems. It continues to show promise, even with the overall size of the construction market shrinking during the latest economic turn down. More than ever, building owners and contractors are seeking buildings and materials that are cost effective but also meet specific code requirements for non-combustible construction (Nowak and Shoemaker, 2012). Cold-Formed Steel (CFS) sections have been recognised as an important contributor to environmentally responsible, sustainable structures in the developed countries, and also a CFS framing is considered a sustainable ‘green’ construction material for low rise residential and commercial buildings (Irw an, et al., 2011)

The term Composite in modern materials engineering is usually referred to a “matrix” material that is reinforced with fibres, since all materials are composed of different subunits if checked at close enough detail (Roylance, 2000). Systems in which steel beams and girders act compositely with concrete slabs, have been used in bridge engineering and building construction (Lakkavalli and Liu, 2006; Lee, et al., 2013) for several decades. The most widely employed system incorporates hot-rolled steel sections with shear transfer between the slab and beam provided by welded headed shear studs (Lakkavalli and Liu, 2006). The application of cold
formed steel composite concrete floor system has gained popularity in North America (Lakkavalli and Liu, 2006) and in small commercial and residential construction (Lakkavalli and Liu, 2006; Lee et al., 2013) in recent years in which concrete is poured onto a corrugated cold formed steel decking. A composite slab comprised of structural concrete cast on cold-formed profiled steel is the most popular type of floor system used in steel framed buildings. The system is well accepted by the construction industry due to the many advantages over other types of floor systems (Abdullah and Easterling, 2007).

‘Ferciment’ or ‘Ferro-cemento’ or Ferrocement is the first invention of reinforced concrete (Jagannathan, 2005; Sasiekalaa and Malathy, 2012). Ferrocement is a type of thin wall reinforced concrete, commonly constructed of hydraulic cement mortar reinforced with closely spaced layers of continuous and relatively small diameter wire mesh (Wang et al., 2004; Gaba and Singh, 2008; Wafa and Fukuzawa, 2010; Eltehawy, 2009). Ferrocement has a very wide applications due to its unique characteristics/mechanical properties, such as: environment friendly, sound technology; excellent tensile strength (Greepala and Nimityongskul, 2006; Noor, 2007; Sasiekalaa and Malathy, 2012), improved toughness, water tightness, lightness, durability, fire resistance, resistance to cracking and cost, time and material effective construction technology cannot be matched by another thin construction material (ACI 549. 1R, 1993; ACI 549R, 1997; Noor, 2007; Sasiekalaa and Malathy, 2012).

Academy of Sciences, (1973), reported that the most extensively used building medium in the world today is concrete and steel combined to make reinforced concrete; familiar uses are in high-rise buildings, highway bridges and roadways. Yet, the first known example of reinforced concrete was a ferrocement boat. Joseph-Louis Lambot’s original French patents on wire-reinforced boats were issued in 1847 not long after the development of Portland cement. This was the birth of reinforced concrete, but subsequent development differed from Lambot’s concept. Ferrocement is a term commonly used to describe a steel-and-mortar composite material. Essentially a form of reinforced concrete, it exhibits behaviour so different from conventional reinforced concrete in performance, strength, and potential application that it must be classed as a completely separate material. It differs from conventional reinforced concrete in that its reinforcement consists of closely spaced, multiple layers of steel mesh completely impregnated with cement mortar. Ferrocement can be formed into sections less than 1 inch thick, with only a fraction of an inch of cover over the outermost mesh layer. Conventional concrete is cast into sections several inches thick with an inch or so of concrete cover over the outermost steel rods. Ferrocement reinforcing can be assembled over a light framework into the final desired shape and mortared directly in place, with a thick mortar paste. Conventional concrete must be cast into forms. These fairly simple differences lead to other, more remarkable differences. Thin panels of ferrocement can be designed to levels of strain or deformation, with complete structural integrity and water tightness, far beyond limits that render conventional concrete useless. Ease of fabrication makes it possible to form compound shapes with simple techniques; inexpensive materials; and, if necessary, unskilled but supervised labour.

1.1 Constituents of Ferrocement:

The constituents of ferrocement are, mortar mix, Wire mesh for reinforcement and skeletal steel.

a) Mortar Mix: - The hydraulic cement mortar mix consists of Portland cement, Fine aggregate, Water and various admixtures as per the requirement. The materials should satisfy standards similar to those used for quality reinforced concrete construction, with particular attention paid to the type of application (Sasiekalaa and Malathy, 2012). It is reported in Naaman (2000), that the mortar mix design can be optimized with available local materials subject to the environmental conditions when the need arise.

b) Wire Mesh for reinforcement: - Steel wire meshes are considered the primary mesh reinforcement. This include the various types of the shape; square woven or welded meshes, chicken (hexagonal/aviary) wire mesh, expanded metal mesh lath etc. Except for expanded metal mesh, generally all the meshes are used galvanized (Sasiekalaa and Malathy, 2012).

c) Skeletal Steel: - Skeletal steel used in ferrocement is in form of welded fabric as a grid of steel rods, strands of small diameters usually 3mm – 10mm. Skeletal reinforcement is needed to form the shape of the structure to be built. Mesh layers are attached around. Skeletal steel is only used when the thickness of the ferrocement element allows.

1.2 Uses of Ferrocement:

According to Sasiekalaa and Malathy (2012), Ferrocement is vastly used in many Building and Civil Engineering works as follows:

i) Residential Buildings
ii) Water tanks
iii) Biogas Holders
iv) Silos
v) Fishing Boats
vi) Roofing Channels
vii) Reservoirs

Review Of Previous Investigations:

A lot of researches were carried out concerning the behaviour, applications etc., of cold-formed steel sections and ferrocement all over the world. Some of the research studies carried out by various researchers on cold formed steel section with concrete on beams and slabs, as well as ferrocement are summarized and presented.

Al-Kubaisy and Jumaat (2000):

Studied the flexural behaviour of reinforced concrete slabs with ferrocement tension zone cover. The effect of the following parameters: percentage of wire mesh reinforcement in the ferrocement cover layer, thickness of the ferrocement layer and the type of connection between the ferrocement layer and the reinforced concrete slab on the ultimate flexural load, first crack load, crack width and spacing, and the load deflection relationship were examined. The results indicated that the use of ferrocement cover slightly increases the ultimate flexural load and increases in the first crack load. The first crack load increased with the increase in the percentage of mesh reinforcement and the ferrocement layer thickness. Considerable reduction in cracks width and spacing (64% - 84%) were observed for specimens with a ferrocement layer. The presence of a cold joint between the reinforced concrete slab and the ferrocement layer lowered the ultimate flexural load by 34% however; cracks width and spacing were reduced.

Hanaor (2000):

Investigated tests of composite beams with cold-formed sections. The study presented designs and test results for several technologies involving cold-formed sections in composite construction, including self-drilling screwed cold-formed shear connectors, and built-up sections bolted to precast concrete planks. The tests included extensive push-out tests of numerous types of connectors, as well as full-scale composite element tests. Results indicated that design of shear connectors can in most cases be conservatively based on codes of practice for the design of cold-formed connections. Full-scale tests indicated high ductility and capacity which exceeds design assumptions.

Masood et al., (2003):

Investigated the performance of ferrocement panels in different environments. The study investigated the performance of ferrocement panels under normal, moderate, and hostile environments. The conditions were created using potable and saline water for mixing and curing. Fly ash, a waste material, was also used as partial replacement of cement. The ferrocement slab panels cast with varying number of woven and hexagonal mesh layers were tested under flexure. Compressive and tensile strength of control specimens and load-carrying capacity of the panels under flexure with and without fly ash were investigated. Result showed that addition of fly ash in different environments affects the flexural strength of panel for both woven and hexagonal wire fabric.

Nakamura (2003):

Studied the Bending Behaviour of Composite Girders with Cold Formed Steel U- Section. The steel U girder is composite with the reinforced concrete slab at the span centre, whereas concrete is poured into the steel U section and pre-stressed at the intermediate supports of a continuous bridge. Bending tests were carried out to investigate the static bending behaviour of the girder models. The girder model at the span centre behaved as a composite beam. The girder model at the intermediate supports behaved as a pre-stressed beam and the filled concrete restricted the local buckling of steel plates in compression. The study showed that the new composite girder has sufficient bending strength and deformation capacity, and the bridge system is practical and feasible.

Nassif and Najm (2004):

Studied an experimental and analytical investigation of ferrocement-concrete composite beams. In study, method of shear transfer between composite layers was examined. Various types of beam specimens with various mesh types (hexagonal and square) were also tested under two-point loading system up to failure. Results showed that the proposed composite beam has good ductility, cracking strength and ultimate capacity.

Hago et al., (2005):

Studied the ultimate and service behaviour of ferrocement roof slab panels. The parameters studied include; the effect of the percentage of wire mesh reinforcement by volume and the structural shape of the panels on the ultimate flexural strength, first crack load, crack load, crack spacing and load-deformation behaviour. The results indicated that the use of monolithic shallow edge ferrocement beams with the panels considerably improves the service and ultimate behaviour of the panels, irrespective of the number of steel layers used.
Inoue et al., (2005):
Investigates the Flexural Behaviour of Cement Composites Panels Reinforced With Different Types of Meshes. In the study, the flexural behaviour of thin cement composite plates reinforced with welded square geo grid mesh and chicken wire mesh with varying number of mesh layers as well as varying percentage of effective reinforcement was presented. A comparison of the load-deflection relationship between the geo grid and chicken mesh composite with 20 and 30 mm thickness was reported. Load carrying capacity of the cement composite elements containing both types of meshes at first crack and ultimate loads was also compared. It was concluded that the first crack and ultimate loads increases with the increase in number of mesh layers for both types of meshes. And the load-deflection relationship fluctuates for chicken-mesh-cement composites whereas it was almost smooth pattern for geo grid-mesh-cement composites with any number of mesh layers.

Jagannathan (2005):
Investigated the flexural and impact strength characteristics of polymer mesh reinforced ferrocement panels. The research examine the behaviour of polymer mesh reinforced ferrocement panels which were evaluated under flexure and impact, and varying the number of layers of polymer mesh reinforcement from 2 to 5. Two types of modifications of the matrix (i.e., mortar admixture and latex modification) and use of polypropylene fibres (fibre contents ranging from 0 - 2.5 %) in additional to the polymer mesh as reinforcement, were considered and the behaviour of ferrocement panels of modified systems, were investigated under flexure and impact. Also behaviour of conventionally reinforced (i.e., using chicken mesh) ferrocement panels were also evaluated under flexure and impact, up to five layers of mesh reinforcement and at identical mesh locations for comparing the performance of polymer mesh reinforced ferrocement panels. Based on the experimental investigations and the analytical study it was concluded that polymeric mesh reinforced panels exhibit linear - elastic behaviour, up to the maximum load and that the load - carrying capacity is nearly the same as that of chicken mesh reinforced ferrocement panels. Of the various matrix modifications considered, incorporation of fibres (polypropylene) has contributed to enhanced performance of polymer mesh reinforced panels, under flexure and impact.

Greepala and Nimityongskul (2006):
Investigated the structural integrity and insulation property of ferrocement exposed to fire. The investigated parameters in the research were thickness of ferrocement, mortar covering and specific surface of wire mesh. The ferrocement specimens had dimensions of 150mm x 420mm (width x length) and consisted of skeletal steel having a diameter of 6 mm spaced at 100 mm centres. Test results revealed that ferrocement specimens met the structural integrity criterion in accordance with ASTM standard. For the insulation property, it was found that an increase in the thickness of ferrocement from 15 to 25 mm significantly increased the insulation performance of ferrocement during the first 75 minutes of fire exposure.

Lakkavalli and Liu (2006):
Investigated an experimental study of composite cold- formed steel C- section floor joists. In the study, twelve large-scale slab specimens and twenty-two companion push-out specimens were tested to study the behaviour and capacity of composite slab joists consisting of cold-formed steel C-sections and concrete. Four shear transfer mechanisms, including surface bond, pre-fabricated ben-up tabs, pre-drilled holes and self-driven screws were employed on the surface of the flange embedded in the concrete to provide shear transfer capacity. Results indicated that specimens employed with shear transfer enhancements showed a marked increase in strength and reduced deflection compared with those relying on a natural bond between steel and concrete to resist shear. Among the three shear transfer enhancements investigated bent-up tabs provided the best performance at both the strength and serviceability limit states, followed by drilled holes in the embedded flanges. The use of self-driven screws resulted in the lowest strength increase.

Abdullah and Easterling (2007):
Worked on the determination of composite slab strength using a new elemental test method. From the study, test results consisting of maximum applied load, end slips and failure modes were recorded and compared with the results of full-size specimens with similar end details, spans, etc. It was showed that the performance of the elemental test developed in the study was in good agreement with the performance of the full-size specimens.

Haddad et al., (2007):
Investigated repair techniques for restoring the structural capacity of heat-damaged high- strength reinforced concrete shallow beams using advanced composites. A series of 16 under-reinforced concrete hidden beams were cast, heated at 600oC for 3 hours, repaired, and then tested under four point-loading. The composites used include high strength fiber reinforced concrete jackets; ferrocement laminates; and high-
strength fiber glass sheets. The beams repaired with steel and high performance polypropylene fiber rein- forced concrete jackets regained up to 108 and 99% of the control beams’ ultimate load capacity, with a corresponding increase in stiffness of up to 104 and 98%, respectively. The beams repaired with fiber glass sheets and ferrocement meshes regained up to 126 and 99% of the control beams’ ultimate load capacity, with a corresponding increase in stiffness of up to 160 and 156%, respectively. Most of the beams repaired showed a typical flexural failure with very fine and well-distributed hairline cracks in the constant moment region.

Noor (2007):

Studied the characteristics of ferrocement encased aerated concrete sandwich wall elements. The research was conducted in two phases. First phase involved the development of high workability and high performance slag-cement based mortar mix to cast proposed ferrocement encasement. The developed mortar was aimed to replace the traditional manual method of plastering the wire mesh by a mechanized casting method. The performance of mortar was investigated in terms of compressive strength, strength development, unit weight, effect of curing regime, and partial replacement of cement by weight with 50% and 60% of slag. The second phase of the study embarked on the development and investigation of the characteristics of ferrocement encased lightweight aerated concrete sandwich wall elements. The parameters studied were compressive strength, flexural strength, failure mode, load-deflection behaviour, load-deformation behaviour, load-strain behaviour, unit weight, water absorption, initial surface absorption uniformity, and role of type and layers of the wire meshes. The results revealed the potential application of ferrocement encasement of lightweight aerated concrete to produce lightweight structural elements which leads towards the industrialization of building system.

Irwan et al., (2008):

Investigated the shear transfer enhancement in precast Cold-Formed Steel-Concrete Composite Beams: Effect of bent-up tabs types and angles. The study investigated ten companion push-out specimens, focusing on the strength and behaviour of a bent-up tabs shear transfer enhancement. The results showed that specimens employed with shear transfer enhancements increased the shear capacities of the specimens as compared to those relying only on a natural bond between cold- formed steel and concrete. In shear transfer enhancements investigated, Bent-up Triangular Tab Shear Transfer (BTTST) provided the best performance in terms of strength. It was therefore concluded that the proposed shear transfer enhancement has sufficient strength and it is feasible.


Investigated an Experimental Study on Ferrocement Channel units under Flexural Loading. The study investigated the strength and behavioural aspects of voided Ferrocement channel type units for precast beams. The variable parameter considered was the number of layers of the wire mesh. The flexural strength of the voided channels was compared with that of solid channels. The test results indicated that the drop in flexural strength with the voids was very negligible compared to the decrease in the weight of the member. The result also showed that the moment curvature response of the voided members under flexural loading improved with the post ductility of the member with increase in the number of layers.

Yardim et al., (2008):

Investigated the performance of precast ferrocement panel for composite masonry slab system. The study investigated the performance of inverted two-way ribs precast ferrocement thin panel as permanent formwork. The two-way inverted ribs in the ferrocement panel enhanced its flexural stiffness, as well as providing link between the precast layer and the in situ elements without shear reinforcement. Flexural behaviours of two precast panels and two composite slabs were investigated under two line load and distributed load. The test results indicated that the thin panel with suitable ribs layout and support distance can be used as permanent formwork.

Eltehawy (2009):

Studied the effect of using ferrocement on the mechanical properties of reinforced concrete slabs subjected to dynamic loads. In the study, he observed the influence of using Ferrocement in enhancement of the mechanical properties of reinforced concrete slabs subjected to impact, penetration and fire. He provides comparison between the performance of using the new technique, as a strengthening material of reinforced concrete slabs and the existing reinforced concrete slabs. The test carried out include; impact load test, projectile impact test using projectile with a diameter of 12.5 mm and the slabs were subjected to high flame of fire up to 700°C for 30 minutes. The result showed that the use of the ferrocement as a reinforcement to concrete slabs enhanced the perforation resistance and reduced the heat transfer through the thinner thickness of the steel mesh reinforced cement matrix.
Al-Rifaie and Muyasser (2010):
Investigated the Structural Behaviour of Ferrocement System For Roofing. In the study, two ferrocement channel-like beams to form I-cross section beam and four ferrocement plates were cast and tested due to flexural loading. The structural behaviour was monitored by reading the deflection and by observing the crack patterns. The measured values of deflections and the observations made indicated that ferrocement can be used in construction of buildings.

Liao and Fang (2010):
Worked on an Experimental Study on Flexural Behaviour of Reinforced Concrete Beams Strengthened with High-Performance Ferrocement. In the study, three reinforced concrete (RC) beams strengthened by high-performance ferrocement and two control specimens without strengthened were investigated when (RC) beams have low compressive strength. Flexural behaviours of strengthened (RC) beams with high-performance ferrocement were evaluated based on comparative analysis with (RC) beams. The flexural capacity, deflection and crack width of (RC) flexural beams were measured, and then comparative analysis was carried out for deformation performance. The test results showed that ferrocement contributed greatly to increase the flexural capacity and raised crack-resisting capacity.

Wafa and Fukuzawa (2010):
Investigated the characteristics of ferrocement thin composite elements using various reinforcement meshes in flexure. The parameters considered in the study include: the effect of the various kinds of reinforcement meshes (stainless steel meshes and E-fiberglass meshes); number of mesh layers and various mesh diameters with opening size as well as various kinds of mortar materials as matrix (cement grout mortar and polymer-cement grout mortar) on the first crack load; bending stiffness; ultimate flexural load; load-deflection behaviour; crack characteristics; energy absorption capacity; and ductility index. The results clarified that the use of stainless steel meshes as reinforcement system in the ferrocement thin composite elements contributed significantly to the improvement of bending characteristics in terms of first crack load, bending stiffness, ultimate flexural load, energy absorption to failure, and numerous fine and well-distributed cracks with a smaller width than while using fiberglass meshes.

Bansal et al., (2011):
Investigated the Effect of Wire Mesh Orientation on Strength of Beams Retrofitted Using Ferrocement Jackets. In the study, effect of wire mesh orientation on the strength of stressed beams retrofitted with ferrocement jackets was studied. The beams were stressed up to 75 percent of safe load and then retrofitted with ferrocement jackets with wire mesh at different orientations. The results showed that the percent increase in load carrying capacity for beam retrofitted with ferrocement jackets with wire mesh at 0, 45, 60 degree angle with longitudinal axis of beam, varies from 45.87 to 52.29 percent. Also a considerable increase in energy absorption was observed for all orientations. However, orientation at 45 degrees showed higher percentage increase in energy absorption followed by 60 and 0 degree respectively.

Irwan et al., (2011):
Investigated Large-scale test of symmetric Cold Formed Steel (CFS)- concrete composite beams with Bent-up Triangular Tab Shear Transfer (BTTST) enhancement. The study, investigated through a symmetric Cold Formed Steel (CFS)-concrete composite beam subjected to a static bending test a new device based on bent-up tab shear transfer enhancement called BTTST. The results had showed that the predicted values of the flexural capacities calculated using a new equation of shear capacity of BTTST agrees reasonably well with the experimental values.

Wehbe et al., (2011):
Studied the development of Concrete/ Cold Formed Steel Composite Flexural Members. The research involved experimental and analytical studies to assess the structural performance and failure modes of concrete/CFS track composite beams and to develop optimum beam configurations for use in Light-Gauge Steel (LGS) construction. The flexural and shear strengths, flexural stiffness, and interface shear transfer were investigated. In the research, only the flexural strength and stiffness were reported. The results showed that concrete/CFS track composite beams can be designed for ductile flexural failure and that the degree of composite action is dependent upon the stand-off screws intensity rather than configuration.

Patil (2012):
Investigated the Performance of Chicken Mesh on Strength of Beams Retrofitted Using Ferrocement Jackets. In the study, RC beams were initially stressed to a prefixed percentage of the safe load and were retrofitted using ferrocement to increase the strength of beam in both shear and flexure. The chicken mesh was
placed along the longitudinal axis of the beam. From the study it was concluded that the safe load carrying capacity of rectangular RC elements retrofitted by ferrocement laminates was significantly increased with chicken mesh used for retrofitting.

**Ramli and Tabassi (2012):**
Investigated the mechanical behaviour of polymer-modified ferrocement under different exposure conditions: An experimental study. In the study, they evaluated the load-deflection characteristics, first crack strength, crack width and crack spacing of three commercial polymer-modified ferrocement namely; styrene-butadiene rubber (SBR), polyacrylic ester (PAE) and vinyl acetate-ethylene (VAE), and unmodified ferrocement elements cured in air and saltwater exposure conditions. The results indicated that continuous saltwater exposure significantly improved the behaviour of polymer modified ferrocements in flexure by exhibiting higher experimental values of the first crack load and ultimate strength of all the specimens. Irrespective of the exposure conditions, polymer modified ferrocements showed lower average crack width than that of the unmodified ferrocement.

**Tawab et al., (2012):**
Investigated the use of permanent ferrocement forms for concrete beam construction. In the study, the feasibility and effectiveness of using precast U-shaped ferrocement laminates as permanent forms for construction of reinforced concrete beams were examined. The experimental program comprised of casting and testing of three control reinforced concrete beams of dimensions 300x150x2000mm and eighteen beams of total dimensions of 300x150x2000mm consisting of a reinforced concrete core cast in a precast U-shaped permanent ferrocement form of thickness 25mm. The performance of the test beams in terms of strength, stiffness, cracking behaviour and energy absorption were investigated. The results showed that high serviceability and ultimate loads, crack resistance control, and good energy absorption properties could be achieved by using the proposed ferrocement forms.

**Lee et al., (2013):**
Investigated the effective steel area of fully embedded Cold-Formed Steel frame in composite slab system under pure bending. The study investigated four types of cold-formed steel frame profiles that were embedded in the concrete to form a new type of composite slab system. Among the arrangement of the specimens tested, it was concluded that S3-DV was predicted to have highest bending resistance than other three types of configuration with condition that the reliability of the prediction need to verify as other factors such as shear bonding and shifted neutral axis happened due to combination of concrete and cold-formed section which, will also contribute the strength capacity of the composite slab system.

**Rethnasamy et al., (2013):**
Investigated Bending Behaviour, Deformability and Strength Analysis of Prefabricated Cage Reinforced Concrete (PCRC) Beams. The study presents comprehensive data and their interpretation on strength, deformation characteristics, ductility and mode of failure of beams in terms of effects of thickness of sheet, concrete strength and amount of tension reinforcement. Eighteen (18) number prefabricated cage reinforced concrete (PCRC) beams specimens and three (3) rebar reinforced cement concrete (RCC) were tested. Nine beams were made with cold-formed steel sheet with average yield strength of 260N/mm² and the rest of the beams with average yield strength of 400N/mm². The result showed that the confinement offered by prefabricated cage prolonged the initiation and propagation of cracks when compared to RCC beams specimens and the beams exhibited well defined post peak behaviour. It was concluded that the PCRC beams exhibits an improved ductility and energy absorption capacity making suitable for seismic resistant structures.

**Conclusions:**
From the previous researches or studies it can be observed that the use of cold-formed steel and concrete as well as that of ferrocement with concrete are reported both on beams and slabs. It is also observed that ferrocement causes less or no deterioration on the structural elements testedas it is with the conventional concrete. But the ferrocement-concrete composites studied which are reported proves to be satisfactory in improving the performance of the structural elements in terms of flexural and impact strengths, ultimate capacity, retrofitting capability, reduced crack width, fire resistance, insulation resistance, energy absorption, ductility, pull-out resistance, shear resistance etc. However, Cold-Formed-Ferrocement Composites has more tendency of improving the overall performance that are required of the structural elements. Therefore, it is highly recommended that investigations using Cold-Formed-Ferrocement Composites is essential.
REFERENCES


