ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Analysis and Design of Isolated and Combined Footing

Shravankumar Kammari
GEO-Technology (M-Tech)

G.Venkatarathnam
Master of Engineering

ABSTRACT:

Conventional isolated footing foundations are built using traditional method of reinforced concrete and utilizing wooden formwork. This wooden formwork often encounters problems such as the formation of rectangular shape which is not consistent, the use of timber which is not environmental friendly and not contributing to the strength, the excessive use of labour to construct, and the difficulty to cast during rainy season. As a result, this method tends to slow down the construction time and affect the quality of the product. Thus, an approach to apply the concept of pre-fabrication and composite construction into the construction of isolated footing foundation has been introduced by using cold-formed steel (CFS) lipped channel sections to replace both the timber as formwork and steel bars as reinforcement.

Currently, the conventional type of foundation is still widely used in local construction, and prefabricated composite isolated footing concept is yet to be seen as an alternative usage in foundation systems. In order to investigate the structural behaviors of the pre-fabricated composite isolated footing foundation, 18 specimens were tested consisting of 6 specimens of conventional footings, 4 specimens of CFS with A10 wire mesh as reinforcement, and 8 specimens of fully CFS with thickness varies from 150 mm to 200 mm, and length varies from 1000 mm to 1750 mm.

All specimens were checked for punching shear, longitudinal shear, and bending moment. The experimental and theoretical calculations were carried out and comparisons were made. The results show good agreement between the experimental works and theoretical values with flexural and shear strength are much higher than the conventional isolated footing.

Therefore, it can be concluded that the proposed pre-fabricated composite isolated footing foundation using CFS lipped channel sections is suitable to be used as isolated footing.

INTRODUCTION:

The on-going demands of construction industry for faster construction process, economical viability, better quality, higher performance and standardized construction method are enhancing the prefabrication concept and gaining in popularity. Being one amongst the prefabrication concept, composite construction has becoming popular in both research and practical aspects. As the concept is commonly understood within the context of building and other civil engineering structures, composite construction implies the use of steel and concrete formed together into a component resulting an arrangement functioned as a single item (Nethercot, 2003).

Cold-Formed Steel (CFS) is commonly used in prefabrication and composite construction for structural application. However, the use of thin plate should be considered with precautious. The thin plate is normally associated with the failure of local buckling before the section reaches yielding point. It tends to buckle elastically under low compressive stress, and also has low torsional stiffness. CFS sections which are braced against lateral or torsional-fllexural buckling may undergo distortional buckling. In composite construction, formworks are used to provide support and containment for fresh concrete, without exception.

Formworks mold the concrete to the desired shape and size, and control its position and alignment. Besides, formworks are functioned to support load of fresh concrete, construction materials, equipment, workers and various impacts loading (Hanna, 1999). Functioning as a structure that transfers loads to the ground, foundations can be generally divided into two categories, namely shallow foundations and deep foundations, depending on depth of load-transfer member and type of load transfer mechanism. Shallow foundation construction is by far the most popular for residential and light commercial building. Currently, the conventional type of foundation known as isolated footing is still widely used in local construction, and prefabrication concept is yet to be seen as an alternative used in foundation systems. Similar to other construction, prefabricated foundations also need to use mold or formwork to provide support and containment for fresh concrete before it is hardened. However, a permanent formwork is functioned not only as formwork but also contributes to strength.The use of CFS in isolated footing to act as permanent formwork seems more beneficial provided that the composite reaction could contribute to the strength.

The practice of integrating CFS into isolated footing is yet to be established and issues related to the design method, materials saving, time saving, and workability need to be addressed. Furthermore, the advantages of using CFS as permanent formwork as compared to conventional wood and reinforced concrete construction in isolated footing structure needs to be investigated. The results derived from the study could be used as a standardized design for the newly proposed foundation system of pre-fabricated composite isolated footing.

Problem Statement

The use of prefabrication for the construction of foundation structures is still low compared to conventional footing method. Therefore, there is a need to encourage local builders and designers to implement this concept in order to speed up the construction time, reduce material usage, and also to guarantee the quality of the construction. The use of prefabricated isolated footing is hoped to enhance the global competitiveness of local builders and designers while the dependency of foreign labours could be reduced. This can be achieved by conducting full scale testing and developed design guide for typical soil bearing for footing design. The use of composite construction in buildings has known to increase the loading capacity and stiffness. With reduced materials usage resulting more slender floor depths and quicker construction (Wright, 2003), these advantages of composite structures have contributed to the dominance of composite beams in commercial building construction. Studies conducted on composite construction have proven thesavings in material usage while achieving the required strength.

By utilising cold-formed steel in pre-fabricated configuration, faster construction time and shape uniformity could be achieved. Based on these assumptions, this study intends to look into the structural behaviour of pre-fabricated isolated footing foundation constructed using cold-formed steel lipped channel section, which could be an alternative to replace the conventional isolated footings currently used.

Research Scope

The scope of the study is limited to the analysis of construction method using cold-formed steel section for foundation system by taking into account of the structural performance. The structural performance is focused on the shear and bending failure. Maximum load derived from these failure loads will determine the load capacity of the proposed footing. The proposed foundation system is only limited to square and rectangular isolated footings.

Experimental tests and analytical studies are to be carried out to evaluate the performance of the proposed steel section by comparing experimental results with the design requirements, as stated in British Standard BS 8110-1:1997, BS 5950-3:1990 and BS 5950-5:1998. The study carried out experimental tests on 18 specimens divided into 3 cases. Details of the specimens are further elaborated in Chapter 3. At the date of this writing, British Standards and Eurocodes are still in coexistence period (BSI, 2004),

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

and hence only British Standard Codes are considered in the design.

Related Work:

Nethercot (2003) reviewed that application of composite construction as early as 1894 which concrete encased beams were used in a bridge in Iowa and a building in Pittsburgh. Later on, other places such as Japan and Europe were seen of such practice in their construction. Documentation to govern the composite construction practice were documented since 1948 in BS 449 code and further extended in CP 117 code, and later replaced by BS 5950-3:1990. Composite construction in Malaysia is currently being popularised under government effort by introducing comprehensive national Industrialised Building System (IBS) by the Construction Industry Development Board Malaysia (CIDB). Badir-Razali building system classified composite construction system as shown in Figure 2.1 (Badiretal., 1998).

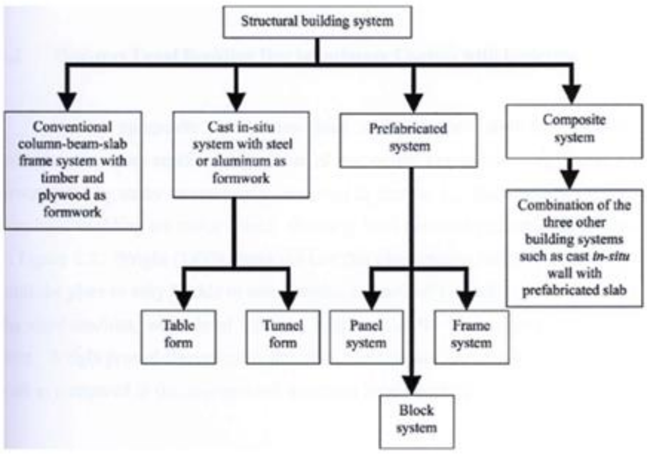


Figure :Badir-Razali building system classification

Various efforts have been made to benefit the composite construction in Malaysia. Abdul Kadiret al. (2006) found significant improvement in labour productivity using IBS rather than conventional building system by up to 70%. Badiret al. (2002) found that quality, speed of construction, and cost savings are themain advantages of IBS. However, Abdul Kadiret al. (2006) pointed out that IBS is still not preferred because of cost factors, and this is further supported by of Haronetal. (2005) which reported cost per gross floor area (m^2) of conventional constructionsystem is lower as compared to composite construction system of single storey low cost house.Oehlerset al. (1994) tried to formulate simple design procedure for their profiled beams. As the flexural behaviour of composite profiled beams is unique, the buckling of the profiled sheet in composite profiled beams is not behave as the standard forms of buckling of thin-plate elements. The steel plate is restricted to deform outwards from the concrete, and the fold lines act as fully fixed support. A procedure was developed to determine the onset of this type of buckling. This form of buckling permits the increase in the width of the plate up to 70%. Oehlerset al.

(1994) also had shown that complete loss of the longitudinal shear strength of the profiled beam only causes a small reduction in the flexural capacity in contrast to large loss in flexural strength that occurs when there is a complete loss in the longitudinal shear strength of standard form of composite steel and concrete beams. Uy and Bradford (1993) continued their effort to carry out experimental and theoretical study on local buckling of thin steel plates in composite construction based on their previous finite strip model (Uy and Bradford, 1996), to derive the design of composite profiled slabs, beams, walls and other composite steel-concrete structural elements.

The comparison of theoretical model based on the finite strip method and experimental test results gave good accuracy.De Andrade et al. (2002) carried out structural assessment of cold-formed composite structures, which consist of a full-scale experimental investigation to study the structural behaviour of composite steel beams made of CFS section shapes filled with reinforced concrete. They found out that the presence of reinforced concrete increased the inertia of the beam which has resulted to the increase in stiffer and consequently leading to smaller deflections than a non-composite solution.Hossain (2005) presented his design on thin-walled composite-filled beams, which comprised of cold-formed open steel box sections with an infill of concrete. The study found out that strength of thin-walled composite beams was limited by compression buckling capacity of steel plate at the top of the open box section. Such strength can be enhanced by stiffening the compression steel plates at the open end of the box section. Helena and Knight (2005) studied about hollow and concrete-filled CFS section subjected to axial and bending forces. They found out from their experiment that the provision of in-fill substantially increases one and a half to two times of the ultimate load carrying capacity using low grade concrete of C25, and one and a half times of the ultimate load carrying capacity by using high grade concrete of C35. Prabhavathy and Knight (2006) also studied on behaviour of CFS concrete infilled rectangular hollow sections connections and frames. Similarly, they found out that provision of concrete infill increases the stiffness and the ultimate moment carrying capacity substantially, irrespective of the axis of loading of the column.

FOOTINGS

Footings are structural elements that transmit column or wall loads to the underlying soil below the structure. Footings are designed to transmit these loads to the soil without exceeding its safe bearing capacity, to prevent excessive settlement of the structure to a tolerable limit, to minimize differential settlement, and to prevent sliding and overturning. The settlement depends upon the intensity of the load, type of soil, and foundation level. Where possibility of differential settlement occurs, the different footings should be designed in such away to settle independently of each other.

Footing Types

The type of footing chosen for a particular structure is affected by the following:

- The bearing capacity of the underlying soil.
- The magnitude of the column loads.
- The position of the water table.
- The depth of foundations of adjacent buildings.

Footings may be classified as deep or shallow. If depth of the footing is equal to or greater than its width, it is called deep footing, otherwise it is called shallow footing. Shallow footings comprise the following types:

Mythology: Footing Design

Reinforced concrete foundations, or footings, transmit loads from a structure to the supporting soil. Footings are designed based on the nature of the loading, the properties of the footing and the properties of the soil.

Design of a footing typically consists of the following steps:

- Determine the requirements for the footing, including the loading and the nature of the supported structure.
- Select options for the footing and determine the necessary soils parameters. This step is often completed by consulting with a Geotechnical Engineer.
- The geometry of the foundation is selected so that any minimum requirements based on soils parameters are met. Following are typical requirements:

Types of Foundations

- Shallow footings bear directly on the supporting soil. This type of foundation is used when the shallow soils can safely support the foundation loads.
- A deep foundation may be selected if the shallow soils cannot economically support the foundation loads. Deep foundations consist of a footing that bears on piers or piles. The footing above the piers or piles is typically referred to as a pile cap.
- The piers or piles are supported by deeper competent soils, or are supported on bedrock. It is commonly assumed that the soil immediately below the pile caps provides no direct support to the pile cap.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Allowable Stress Design and Strength Design

- Traditionally the geometry of a footing or a pile cap is selected using unfactored loads. The structural design of the foundation is then completed using strength design in accordance with ACI 318.
- ACI Committee 336 is in the process of developing a methodology for completing the entire footing design using the strength design method.

Development of Pre-fabricated Isolated Footing

- Researches in composite constructions were mainly concerning the basic component of a building like beams, columns, slabs, connections, and frames; but yet not extended into foundation structures. Researches in shallow foundations mainly assumed a rigid footing condition.
- These relevant previous studies could be served as valuable guides to develop research work on structural performance of pre-fabricated isolated footing. Given the scope of this research is on the structural performance, hence, only the structural
- aspects of the isolated footing foundation will be considered for the research work, and itis covered in Chapter 3 Section 3.2 of this writing.
- BS 8110-1:1997 covers design of reinforced concrete for structural elements of beam, slab, column, wall, staircase, and base. The code provisions the design shear strength and other design aspects for the isolated footing to share the same calculation method. For the purpose of structural analysis, it could be generalisedthat isolated footing can be simplified as a slab with a short column on its top.
- BS EN 1990:2002 points out that in order to provide a structure that corresponds to the requirements and to the assumptions made in the design, appropriate quality management measures should be in place.

Thus, BS EN 14991:2007 provides evaluation of conformity to the completed precast foundation elements which are supplied to the market and covers all the production operations carried out in the factory with the design rules referred to BS EN 1990:2002.

Concluding Remarks

After review, it can be concluded that the concept of IBS and composite construction practise are becoming popular in Malaysia. However, the application of composite construction in building using cold-formed steel sections as isolated footing foundation is very new and with the development of standardised table, the popularity of this system can be enhanced. By assuming a load applied at the column stump with the end of the footing is simply supported, the proposed pre-fabricated composite isolated footing can be tested with relatively easier method for assessment of structural .

EXPERIMENTAL AND THEORETICAL ASPECTS OF ISOLATED FOOTING

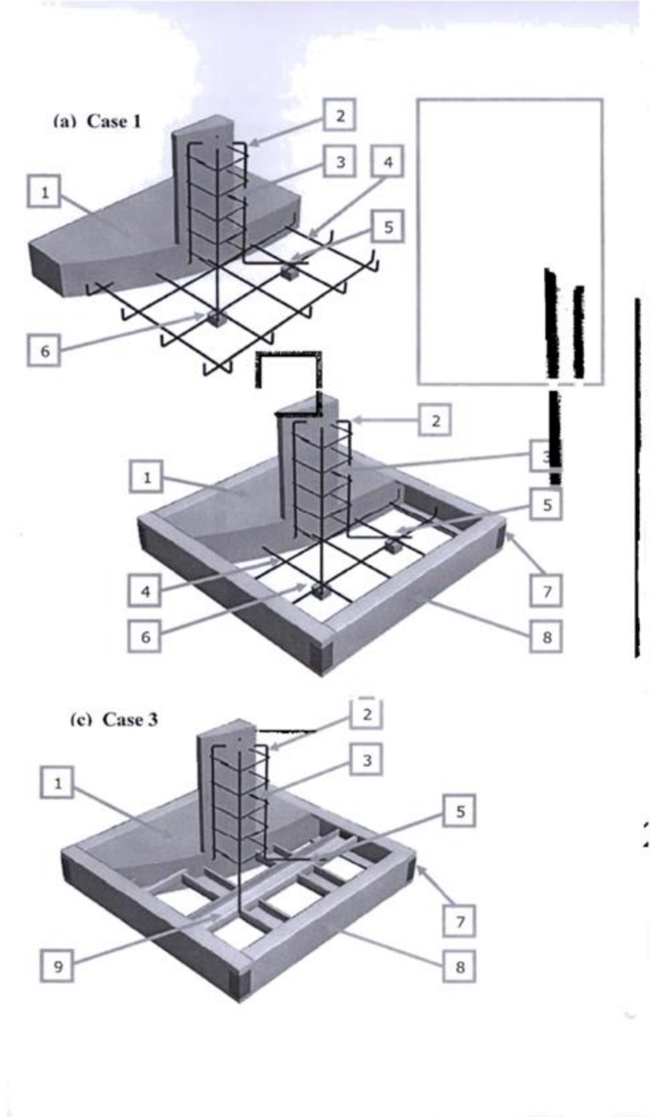
This chapter discusses the experimental works carried out to investigate the performance of the proposed isolated footing using cold-formed steel section (CFS) sections and the conventional reinforced concrete isolated footing. The theoretical aspects for both the proposed and the conventional isolated footings by considering moment, shear and axial capacities are also considered. The experimental and theoretical results are compared and discussed in details. The experimental works in the laboratory is divided into three cases which are Case 1, Case 2 and Case 3.

The Case 1 specimens consists of 6 conventional reinforced concrete isolated footing, the Case 2 specimens consists of 4 specimens with formwork using CFS and using A10 wire mesh as reinforcement bars, and the Case 3 specimens consists of 8 specimens with both the formwork and the reinforcement bars are from the CFS section. Figure 3.1 shows the illustration of the specimens for all the three cases. Tensile tests and cube tests are also carried out to investigate the material properties.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Specimens and Materials Details

A total of eighteen isolated footing specimens were tested until failure and the results were recorded together with failure mode. Prior to commencement of the tests, several tests were carried out to investigate the material properties of concrete and steels. These were done so that the correct design mixture for concrete strength could be established and also the actual strength of steel could be achieved. Preparation of all specimens is covered in Section 3.3 of this thesis.



For concrete strength, slump tests were carried according to BS EN 12350-2:2000 to ensure workability of the concrete. Only concrete which yield a true slump (a slump in which the concrete remains substantially intact and symmetrical) with measurement of 50 mm to 80 mm were used. Concrete samplings were conformed to BS EN 12350-1:2000. The mould of size 150 mm was used for cube casting based on BS EN 12390-1:2000. Cube tests were conducted after curing using TONIPAC 300 Testing Machine, in compliance to BS EN 12390-3:2000 for 7-day and 28-day to determine the strength of the concrete. Figure 3.2 shows the cubes cast in the moulds and Figure 3.3 shows the cubes prepared for cube tests after casting. Figure 3.4 shows the TONIPAC 300 Testing Machine used for cube tests. Figure 3.5 shows the steel reinforcements, links, and CFS lipped channel sections prepared for tensile and coupon tests. Figure 3.6 shows a conventional graph generated from the tensile test to determine the properties and the characteristic values of the specimen.

Figure 3.2 the cubes cast for the cube tests

Conclusions:

- ✓ The foundation is a part essential of a structure, because permits the transmission of loads from the structure to the soil. The mathematical approach suggested in this paper produces results that have a tangible accuracy for all problems, main part of this research for find the solution more economical.
- ✓ The model presented in this paper applies only for design of boundary combined footings, the structural member is assumed to be rigid and the supporting soil layers elastic, which meet expression of the bidirectional bending, i.e.,

the variation of pressure is linear. The suggestions for future research, when is presented another type of soil, by example in totally cohesive soils (clay soils) and totally granular soils (sandy soils), the pressure diagram is not linear and should be treated differently

REFERENCES:

Abdul Kadir, M.R., Lee, W.P., Jaafar, M.S., Sapuan, S.M., Ali, A.A.A. (2006). Construction Performance Comparison Between Conventional and Industrialised Building Systems in Malaysia. Structural Survey.Volume 24 No 5.Emerald Insight. 412-424

Arumugasaamy, P. (2006). Structural Design of Foundation.In Gunaratne, M. (Ed.).

The Foundation Engineering Handbook (Page 179-234). Boca Raton: Taylor& Francis Group, LLC.

Badir, Y.F., Kadir, M.R.A. and Ali, A.A.A. (1998).Theory of Classification on Badir-Razali Building System Classification.Bulletin of Institution ofEngineers, Malaysia.

Badir, Y.F., Abdul Kadir, M.R., and Hashim, A.H. (2002).Industrialized Building Systems Construction in Malaysia.Journal of Architectural Engineering, March 2002. 19-23.

Bond, A. and Harris, A. (2008).Decoding Eurocode 7. Oxon: Taylor & Francis.

British Standards Institution (1990).BS 5950 Part 3. Structural Use of Steelwork inBuilding - Design in Composite Construction. London: British StandardsInstitution.

British Standards Institution (1998).BS 5950 Part 5. Structural Use of Steelwork inBuilding - Code of Practice for Design of Cold Formed Thin Gauge Sections.London: British Standards Institution.