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# Cold-formed steel section with Bolted Connection- A review

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**ABSTRACT**

A wide variety of open-section cold-formed steel (CFS) sections may be made by rolling or pressing thin gauges of sheet steel into the shape of channel sections, Z sections, hat sections, and other shapes. For both residential and commercial projects, the usage of CFS as a structural framework has increased during the last several years Therefore, it is important to study how CFS parts interact and what that means for the whole system. With a focus on Euro code 3: BS EN 1993-1-3 and Euro code 3: BS EN 1993-1-3-8, design specifications for bolted connections of CFS sections, previous research is reviewed. In this study, the results of prior research are described.

**"Keywords:**review,cold-formedsteel,boltedconnection,finiteelementmodelling.

## 1.INTRODUCTION"

These days, many building companies are striving for more sustainable growth by constructing structures with less resources. Steel is the most recyclable material in the world, allowing for lighter, more fuel-efficient automobiles and safer, higher constructions. Steel member's better sustainability performance reduces environmental impact over the whole life cycle compared to competing materials. The two primary types of structural steel are hot-rolled and cold-formed [1]. "A blast furnace or electric arc furnace[2] is used to forge hot-rolled steel, while cold-formed steel is manufactured by rolling or pressing thin sheets of steel into items at room temperature.[3][4][5] Since hot-rolled and cold-formed steels differ greatly in their strength and structural performance, the production method is important to their performance."

When it comes to automobiles, energy, machinery, and other large-scale machinery and equipment, steel has become a go-to material for many different companies. Energy, transportation, and water infrastructure all rely on steel as a key component, as do commercial and residential construction projects alike. Industry seems to be warming up to new goods and technology, such the Industrial Building System (IBS). According to the Malaysian Iron and Steel Industry Federation, Malaysia had a 15.3% rise in steel imports in 2016 compared with 2015. (MISIF). One-quarter of the country's total imports of steel come in the form of hot-rolled steel, cold-rolled steel, and bars. A 41 percent reduction in ASEAN exports of steel goods from 2.3 million tons in 2015 to 2.22 million tons last year is a fall of 2.7 percent. Cold-rolled steel products account for 25% of exports, while pipes and tubes account for 23% and galvanized sheets account for 11% of all steel exports. "Even though exports of Malaysian steel are declining, this data shows that cold-rolled or cold-formed steel sections are still extensively used in the country's manufacturing process.

Cold-formed steel (CFS) sections, which are manufactured by cold-rolling or brake-pressing into different forms, might be beneficial to building buildings because of their low density and low weight (such as channels, Z-sections, hat sections, and other open sections)." A typical yield stress for cold-formed members is 350 MPa for regular steel and lately as high as 550 MPa for high strength steel [6]. Section thicknesses are normally between 1 millimeter and 3 millimeters. As a result of cold rolling, strain hardening causes a greater rise in yield strength [7]. [7] Strain aging causes a loss in ductility and a rise in ultimate strength, both of which are dependent on the metallurgical qualities of each individual material.

There has been an ongoing supply of CFS available for sale since steel mills began producing flat sheets of steel over a century ago. During the 1850s, CFS members were employed in the construction of structures in America and Great Britain. CFS construction materials were not widely accepted in early 20th and early 30th century since there was no appropriate design standard and inadequate information on their use at that time in building standards. When the Virginia Baptist Hospital was built in Lynchburg, Virginia, in 1925, it was one of the earliest examples of the usage of CFS as a construction material. Cold-formed steel has come a long way since its first use in construction.

In the last several decades, the use of CFS as a structural frame for residential and multi-story commercial structures, such as roof systems, wall studs, girts, and steel-framed houses, has increased significantly. [8]. Since cold-formed steel has properties that make up for the drawbacks of traditional goods, this has become possible. In order to enhance the structural function of a structure and its aesthetic appeal at a cheaper cost and with more ease of use than traditional materials such as concrete, fiber-reinforced plastic (CFS) has become increasingly popular among architects, engineers, and constructors. To support claddings on exterior building envelopes, hot-rolled steel sections are usually used, whereas CFS sections are employed as secondary structural components.

"There are design codes for cold formed steel structures available, such as those issued by AISI (1996), the British Standard (1998), and Eurocode 3: Parts 1-3, for typical usage of cold formed steel sections (2006). Design guidelines and comments for cold formed steel buildings, on the other hand, are accessible. CFS members in Europe are designed using Eurocode 3 (EN 1993-1-3) and Eurocode 8 (EN 1993-1-8), whereas in the United States researchers turn to the American Iron and Steel

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Institute (AISI). Large width-to-thickness ratios in cold-formed steel members, which are unusual in hot-rolled steel, raise concerns about the integrity of the structure as a whole. [9] Cold-formed steel connections' design guidelines are limited to their fundamental behavior, unlike hot-rolled steel joints. Because of the wide variety of possible configurations and the specific nature of their intended usage, cold-formed steel joint profiles seldom have elaborate design techniques. Since cold-formed steel (CFS) is a widely used building material, this study evaluates the bolted connections between CFS sections in light of prior studies. BS EN 1993-1-3 and BS EN 1993-1-8 are the design standards Malaysia uses, and this research will focus on the design guidelines from these two standards. Eurocode 3: BS EN 1993-1-3:2006 offers extra requirements for cold-formed components and sheets, while Eurocode 3: BS EN 1993-1-8 gives design guidelines pertinent to connection.

**CFSSECTIONSANDITSAPPLICATION**

Cold-formed members and profiled sheets are made from coated or uncoated hot- or cold-rolled flat strips or coils. Their cross section may be either constant or variable as long as it does not exceed the permitted limits [10]. Both cold-formed structural members and panels and decks are the basic types of structural frame members. Single open sections, open built-up sections (Figure-1.b), and closed built-up sections (Figure-1.c) may be found in the different structural elements (Figure-1.c)."

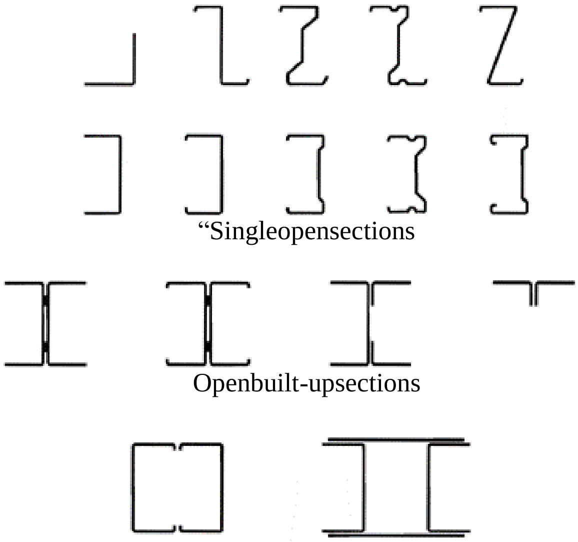


**Figure-1.**Typicalformsofsections forcold-formedmembers[10]."

It is common for bar members to have a thickness of 0.5 to 6 millimeters, although this may vary widely. The thickness of the panel is generally 20 to 200 mm, and the depth is typically between 20 and 200 mm, with the thickness ranging from 0.4 to 1.5 mm. Cold-formed steel sections and sheets may benefit from stiffeners at the edge and in the middle. In order to strengthen sections using these stiffeners, the flat plate parts of the sections may be supported out of plane. [11] claims that the CFS material's efficiency may be increased by up to 50% using stiffeners.

In addition to its excellent strength-to-weight ratio, cold-formed steel sections may be molded into many different cross-sectional shapes, are inexpensive to build, and are very adaptable [12]. Along with excellent yield strength and great constructability, the long-term durability of CFSs is also a strong attribute [6]. CFS sections offer numerous benefits, but they also have significant drawbacks when used in cold-formed steel construction. Because of their thin walls and poor torsional stiffness, CFS components are more susceptible to be deformed in a torsional fashion. Cold-formed steel sections are often made up of plate parts with a wide width-to-thickness ratio. It is difficult to optimize CFS sections because of their huge flat width-to-thickness ratios, which make them vulnerable to local, distortional and global buckling modes, notably in the domains of structural stability and joints.

**"BEHAVIOURANDDESIGNRESISTANCEOFCFS"**

Distortive and shearing effects According to the criteria of BS EN 1993-1-3 [10], Cross-sectional strength and stability tests were performed on the optimized CFS sections, taking into account both local and distortional buckling modes. The local buckling of cold-formed steel pieces necessitates consideration in the design process. If the element's maximum e/e0 moment value at any cross section is greater than Wplfyb/M0=, the resistances associated with that element's slenderness must be reduced. Using Eurocode 3 Part 1-3, a cross section's design resistance may either be estimated, or it can be created with the help of testing. It is possible to use design assisted by testing in place of calculation for any of these resistances. Particularly beneficial is the use of testing to help in the design of cross sections with relatively high width-to-thickness ratios such as inelastic behavior, web crippling, or shear lag Cross-sectional distortion of members must be taken into consideration while designing, especially when designing members with compression flanges, to prevent lateral buckling and bending of flanges. For the relative web slenderness w, use the value in Table-1.

Table-1. Shear buckling strength fbv [10].

| **Relativewebslenderness** | **Web without stiffening at thesupport** | **Web with stiffening at thesupport**[1] |
|---|---|---|
| $\lambda_w \leq 0.83$ | 0.58 $f_{yb}$ | 0.58 $f_{yb}$ |
| $0.83<\lambda_w<1.40$ | $0.48f_{yb}/\lambda_w$ | $0.48f_{yb}/\lambda_w$ |
| $\lambda_w \geq 1.40$ | 0.67 $f_{yb}/\lambda^2_w$ | $0.48f_{yb}/\lambda_w$ |
| [1]Stiffeningatthesupport,suchascleats,arrangedtopreventdistortionofthewebanddesignedtoresist thesupportreaction.” | | |

“The relative web slenderness w will be calculated as follows:

Failuremodeofboltedconnection

In classical analysis and design, connections in bare steel frames are usually seen as either pinned or secured.” Pinned connections assume that in the ideal circumstance, no time has elapsed between the beam and the column. The beam and column joined by a pin must comply with serviceability limit states since rotation is a major problem for such junctions. Typical failure mechanisms for bolted connections include tearing out of the sheet material, shearing of the bolts, netting failure, and any combination of these failure modes and their combined effects. It is clear from Figure 3 that shear is the primary driver of these failure types. When the bolt is near to the plate's edge or the gap between succeeding bolts parallel to the force line is very small, tear-out failure is more frequent.. The edge of the plate or an adjacent bolt hole may be damaged if a section of the plate breaks away in the centre. Additionally, a software failure mode known as failure mode in tension is another possible occurrence. The failure mode is shown in Figure 4. Bolted connections have minimum edge and spacing distances set in design regulations to prevent this kind of failure. Hancock et al. propose that bearing failure may occur as long as the edge and spacing lengths are big enough. It is possible that a failed bearing may cause the bolt hole to expand on one side, encasing the sheet metal on the other.

They postulated that the introduction of washers beneath the bolt head and nut significantly increased connection resistance against bearing failure in an experiment since CFS had such thin walls in most spots. The sheet may fail across the bolt hole if the net portion of the linked sheet experiences significant stresses. The connecting point has the lowest cross-sectional area of the sheet, making it the weakest element of the structure. In each connection, the net stress rises in direct proportion to the number of bolts. The net section of solid sheets without perforations other than the bolt holes is typically dictated by the spacing arrangements. To avoid this problem, be sure that the grade of bolt you select has enough shear strength to withstand loads larger than those of either the sheet or the connecting arrangement in total. The bolt may fail in either a single or double shearing failure depending on the connection arrangement. As the failure is so delicate, it is undesired.

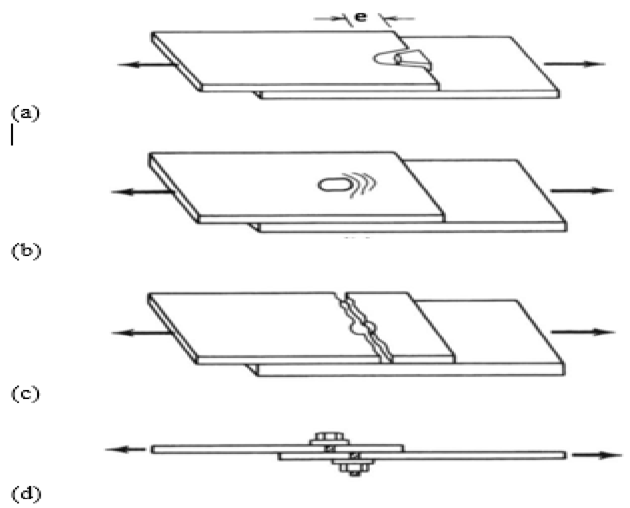


Figure-3.Failure modesofboltedconnectionsinshear:a)tear-out failure of sheet, b) bearing failure of sheet, c)tensionfailureof netsection,d)boltshearfailure.

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Figure-4.Failuremodesofboltedconnectionsintension[7].

**DesignofboltedconnectionforCFS"**

In accordance with EN 1993-1-8, cold-formed steel section connection design procedures must be adhered to. Parts 1-8 of Eurocode 3 define connections and joints, respectively. In cold-formed steel sections, the distinction between connections and joints is negligible. Cold-formed steel structures are encouraged to use elastic analysis for joint design. Shear, stress and moment-resistant bolted connections are often used in cold formed steel frames. It is possible to create bolted connections by utilizing the fundamental formula (1) and the partial factor M2 = 1.25, which includes the resistance values shown below.

**"Table-2.** Design resistance for individual fastenerssubjected to shear and/ortension[16].

| **Failuremode** | **Bolts** |
|---|---|
| Shearresistancepershearplane | $F_{v,Rd} = \frac{\alpha_v f_{ub} A}{\gamma M2}$ |
| Bearingresistance | $F_{b,Rd} = \frac{k_1 \alpha_b f_u d t}{\gamma M2}$ |
| Tensionresistance | $F_{t,Rd} = \frac{k2 f_{ub} A_s}{\gamma M2}$" |

Bolt bearing resistance may be split into two categories: static and dynamic. Because of this, bolts in larger holes have a bearing resistance of 0.8 times greater than bolts in standard holes. Bolts that are installed into slots have a bearing resistance that is about 0.6 times greater than that of bolts that are installed into round or oval-shaped holes.

**PREVIOUSRESEARCHONCFSBOLTEDCONNECTION**

Torsional stiffness is low in cold-formed sections due to their short width. Cold-formed steel sections have been studied extensively in the past several decades regarding the behavior of bolted connections. Thin-walled steel members that have good strength-to-weight ratios are often used in lightweight steel sections in order to reduce the cost of construction. It is important to note, however, that this material has a tendency to buckle. As a result, cold-formed steel sections, especially those with bolted connections, may be studied in the lab and numerically modeled.

**Laboratorytestingandfiniteelement modelling**

C-sections used as beam and column members in an experiment had a moment resistance of four bolts per member that varied from 42% to 84% of the CFS members' capability for coping with moment loads, according to the findings of the researchers Two C-shaped portions of the model with four bolts per member were found to be appropriate and cost-effective for use as a test model. Chung also looked at the structural performance of bolted connections between CFS sections in beam-column subframes. There were eight different ways to join the double-lipped C-sections, which were welded together with 10mm and 16mm hot rolled steel gusset plates, respectively, to each other. Both gusset plates contain four bolts, although they have different forms. A total of three failure mechanisms were discovered throughout the investigation. Measured moments varied from 36-97 per cent, making the design both structurally and cost-effective.

Web cleats of CFS strips were employed in the CFS testing of Chung et al. in order to study structural performance of the shear resisting connection of CFS section. A total of 24 tests were performed using four distinct connection setups. Web cleats and bolts have been shown to be a suitable shear-resistant connection in building construction. An easy and effective connecting of

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CFS sections improves building efficiency. Researchers Chung and Ip [6] looked upon CFS bolted connections using finite element analysis. Because of the reduced pliability of shot associations manufactured with high-strength steel, it was determined that the plan rules were not relevant. A semi-exact plan recipe for the bearing opposition of shot associations was provided. Keeping up the pressure on CFS organizations is made possible by the proposed strategy. Studies conducted by Wong and Chung indicated an 86% increase in second limits for 20 segment base association tests. The use of this method enabled the transmission of time between the linked sections.

According to an investigation by Ju, Fan, and Wu, limited component studies show that the bolt apparent powers measured from the limited component studies are almost linearly related to the total number of bolts in an association. Even though it was perfectly acceptable to overlook any influence on twist and bolt bending while trying to determine a decisive load for the association with enough bolt splitting and end distance. For the mathematical examination of semi-unbending associations regarding rotational spring firmness, a limited component program was developed, and it was found that semi-inflexible bar to-segment and section to-establishment associations were more viable on broad primary behavior than steel support and bracket part associations with joints.

When it comes to the fundamental behavior of an outline, the firmness and execution of section foundation linkages have a substantial impact. Ali, Saad, and Osman concluded that a sensible method may be used to develop a feasible CFS outlining. To determine the principal exhibitions of different bar segment groups with shot second affiliations on CFS regions, Kaling, Patil, and Hosur used FEM and trial testing, and the results showed a torsional clasping framework was responsible for the failure. As you can see in Figure 5, we used a FEM model and a standard trial setup.

**CONCLUSIONS**

Engineers and contractors are increasingly using cold formed steel products because of their improved strength, light weight, and non-combustibility, as well as their simplicity of manufacture. In addition to improving structural performance and building aesthetics, cold-formed steel products may reduce construction costs while improving structural functioning.

For the design of a bolted connection according to the Eurocode 3 Part 1-8, various considerations are necessary. Cold-formed steel presents a distinct failure mechanism and substantial deformation as the buckling is the primary issue in connection structural analysis because of its thin-walled nature. When designing bolted cold-formed steel connections, the formulae in Eurocode may be erroneous since they were originally created for hot-rolled steel joints. This is why it is necessary to do extensive investigations on the dependability of connection design according to CFS rules of practice. For bolted connections in cold form steel sections, researchers may utilize numerical modeling as an alternative to costly and time-consuming laboratory testing to find out their behavior without incurring additional costs. To corroborate numerical modeling data, however, laboratory testing is still necessary.

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