A SYSTEMATIC LITERATURE REVIEW: BENDING FAILURE IN COLD-FORMED STEEL BEAM

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I hereby declare that all corrections and comments made by the supervisor(s)and examiner have been taken into consideration and rectified accordingly.

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A SYSTEMATIC LITERATURE REVIEW: BENDING FAILURE IN COLD-FORMED STEEL BEAM

By

NUR ALIA BINTI AHMAD FAUZI

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I, NUR ALIA BINTI AHMAD FAUZI hereby declare that I have checked and revised the whole draft of dissertation as required by my supervisor.

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Date: 16.07.2022

SHOULD BE STAMPED BY THE GENERAL OFFICE OF THE SCHOOL OF CIVIL ENGINEERING, UNIVERSITI SAINS MALAYSIA

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ABSTRAK

Kegagalan lenturan dalam rasuk keluli terbentuk sejuk merujuk kepada kegagalan yang berlaku di bahagian keluli rasuk apabila ia bengkok. Rasuk keluli terbentuk sejuk terdedah kepada pelbagai senario lenturan dan ia sepatutnya dapat mengendalikan pelbagai mod lengkokan. Kajian literatur secara sistematik daripada tiga puluh lima kertas digunakan untuk menilai kegagalan lenturan dalam rasuk keluli terbentuk sejuk. Tujuan kajian ini adalah untuk memberikan kajian secara sistematik mengenai kesan lenturan pada mod kegagalan bahagian keluli terbentuk sejuk, serta kaedah menjalankan kajian, iaitu berbentuk eksperimen atau berangka. Apabila rasuk keluli terbentuk sejuk melentur, mod kegagalan yang paling biasa adalah lengkokan tempatan, lengkokan global, buckling lengkok-kilas sisi, dan lengkok-ricih. Mod kegagalan lenturan dalam rasuk rasuk keluli berbentuk sejuk dikaji untuk melihat bagaimana ia dipengaruhi oleh beberapa parameter seperti sifat keratan, geometri bahagian, bahan tambahan, kekuatan, keanjalan, pemuatan, dan faktor rintangan spesimen. Oleh itu, kaedah yang digunakan untuk menyiasat kegagalan lenturan dalam rasuk rasuk keluli berbentuk sejuk juga telah disiasat. Kajian ini menyimpulkan bahawa ujian "four-point bending" dan kaedah elemen terhingga adalah kaedah eksperimen dan berangka yang paling biasa digunakan bagi menyiasat mod lengkokan apabila keluli terbentuk sejuk terdedah kepada lenturan.

ABSTRACT

Bending failures in cold-formed (CFS) steel beams refer to failures that occur in the steel section of a CFS beam when it is bent. Cold-formed steel (CFS) beams subjected to various bending scenarios should be able to handle various buckling modes. The systematic literature review from thirty-five papers are used to assess bending failure in cold-formed steel beams. The purpose of this study is to provide a systematic review of the literature on the effect of bending on the failure mode of cold-formed steel (CFS) sections, as well as the method of conducting the study, which can be experimental or numerical. When CFS is bent, the most common modes of failure are local buckling, global buckling, lateral-torsional buckling, and distortional buckling. The failure mode of bending in a CFS beam and the parameters that affected the failure mode of CFS beam in bending have been studied. The parameter affected the failure mode such as section properties, section geometries, additional materials, strength, elasticity, loading, and specimen resistance factor are found. However, the method used to investigate the bending failure in the CFS beam also has been investigated. This study concluded that the four-point bending test and the finite element (FE) method are the most commonly used experimental and numerical methods, respectively.

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List of Abbreviation

SLR	Systematic Literature Review
CFS	Cold-formed Steel
FE	Finite Element
FEA	Finite Element Analysis
FEM	Finite Element Method
RQ	Review Question
RO	Review Objective
L	Local
L+D	Local-distortional
LB	Local Buckling
GB	Global Buckling
TB	Torsional Buckling
DB	Distortional Buckling
LB+TB	Local-Torsional Buckling
FB	Flexural Buckling
FB+TB	Flexural-Torsional Buckling Flexural-Torsional Buckling
EC, EN	Eurocode
AS/NZS	Standard Australia and Standard New Zealand
IS	India Standard
KS B	Korea Industrial Standard
AISI	American Iron and Steel Institute
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
EC	Exclusion Criteria
IC	Inclusion Criteria
DE	Data Extraction
Q	Question Regarding Information
UK	United Kingdom
PSO	Particle Swarm Optimisation
PP	Polypropylene

CHAPTER 1

INTRODUCTION

1.1 Background

Steel is a "green" substance that is good for the environment. It is recyclable and reusable. Steel-framed house minimizes the number of trees used in residential construction, helping preserve one of nature's most valuable resources. Hot-rolled steel and cold-formed steel are the two forms of steel used in construction. Cold-formed steel structural members are geometries made from steel plate, sheet, or strip that are commonly used in construction. In addition, the weight of cold-formed steel is much less than that of wood and masonry. The material is formed by either press-braking or cold roll-forming to create the desired shape throughout the manufacturing process. Corrugated steel roof and floor decks, steel wall panels, storage racks, and steel wall studs are all examples of cold-formed steel. For the manufacturing of small quantities of simple shapes, press-braking is frequently utilized. The most common process for producing roof, floor, and wall panels is cold roll forming (Helen Chen et al, 2012). Cold-formed steel sections have several advantages, including a high strength-to-weight ratio, flexibility in creating diverse cross-section forms, and ease of fabrication. By cold-rolling or brake-pressing, cold-formed steel sections are commonly shaped into channel sections, Z-sections, hat sections, and other open sections. The width-to-thickness ratio of the plate parts that make up cold-formed steel sections is usually quite high. As a result, for cold-formed steel members, local buckling and distortional buckling are the most common failure mechanisms.

Because of their thin thickness and open-section nature, cold-formed steel beams may be more prone to cross-sectional deformation than hot-rolled steel beams. To predict the effect of cross-sectional deformation on overall beam bending behavior, one must first understand how individual segments deform within the cross-section. The cross - sectional deformation in channel-section beams when subjected to transverse bending loadings is mainly caused by the flange curling, which results in a reduction of the overall flexural rigidity of the beams (Dai and He, 2021).

1.2 Problem Statement

When a beam is bent completely, the bending forces on the top and bottom layers of the beam are in opposite directions. Buildings and other load-bearing constructions are using cold-formed steel beams increasingly. When cold-formed steel beams are subjected to bending loads, the interaction between the transverse bending of the beam and the in-plane flattening of the beam cross-section leads to nonlinear bending behavior. However, it was discovered that only a few studies on cold-formed steel beams exposed to bending have been documented and covered. Therefore, in this research, the bending failures of the CFS beam will be figured out using a systematic literature review method based on previous research and analytical or numerical data.

1.3 SYSTEMATIC LITERATURE REVIEW (SLR): REVIEW OBJECTIVES

Only a few studies on cold-formed steel beams exposed to bending were discovered to be documented and covered. Furthermore, the method of conducting numerical and experimental studies on CFS is not discussed in detail in any research. As expected in this review, various numerical and experimental studies have been conducted to investigate the bending behaviour of the CFS beam.

Some analyses will take into account non-uniform and uniform bending in the experimental testing of CFS steel. However, due to the simulation of a realistic bending condition, only non-uniform bending behaviour will be studied in this review. The review objectives of this work will be how the bending behaviours will affect the mode of failure of CFS and their results. As a result, the following are the review objectives of this thesis:

Table 1.1: Review Objectives

NO	REVIEW OBJECTIVES
RO1	To investigate the mode of failure in cold-formed steel beam subjected to bending
RO2	To review the factors that influenced the failure in CFS beam when subjected to bending
RO3	To examine the result from existing numerical and analytical test on cold-formed steel beam subjected to bending

1.4 SYSTEMATIC LITERATURE REVIEW (SLR): REVIEW QUESTIONS

RQ1 was developed to comprehend the type of behaviors and mode of failures of CFS beam when subjected to bending. RQ2 seeks to investigate the factors that influence the bending failure in CFS beam. Finally, the RQ3 was developed to recognize the method used to investigate the bending failure in CFS beam. Table 1.2 shows the review questions.

Table 1.2: Review Questions

NO	REVIEW QUESTIONS
RQ1	What are the behaviours of CFS beam when subjected to bending?
RQ2	What are the factors that influence the bending failure in CFS beam?
RQ3	What are the methods used to investigate the bending failure in CFS beam?

1.5 CONTRIBUTION AND IMPORTANCE

Cold-formed steel is uniform in quality, suitable for mass production, and light in weight. It is widely used for both structural and nonstructural members in buildings. In addition, the weight of cold-formed steel is much less than that of wood and masonry. As a result of cold-forming process, cold-formed steel possesses one of the highest strength-to-weight ratios of any building materials. This high strength and stiffness advantage mean better design flexibility, wider spans and better material usage.

However, CFS, on the other hand, has lower bending capacity, which causes failure. CFS bending failure performance should be further investigated in order to make the following contributions:

- Improve the bending capacity of CFS beam by utilizing the factor that affected the failures.
- Assisting engineers and designers in determining the type of steel to be used in a given situation.

- Extending the use of CFS by utilizing its benefits in future construction projects.

1.6 OVERALL THESIS STRUCTURE

In order to achieve the objectives, this thesis is divided into five chapters. The first chapter will serve as an overview of this study. Chapter 2 will present a protocol for conducting a systematic literature review in order to identify relevant scholarly sources for the bending failures of CFS beams under review. A systematic literature review (SLR) based on over 30 previous research papers is conducted in Chapter 3 to provide a better understanding of the research by evaluating and analysing related and existing works. In Chapter 4, the SLR findings for each of the three review questions (in Section 1.4) will be reported and discussed. In Chapter 5, the findings will be used to draw a conclusion and make recommendations based on the findings.

CHAPTER 2

METHODOLOGY: SYSTEMATIC LITERATURE REVIEW(SLR)

2.1 Introduction of Systematic Literature Review (SLR)

SLR is a predetermined and established method, procedure, or protocol for collecting, reviewing, and evaluating a body of literature. Secondary research can be carried out in a variety of ways, including SLR. The important goal of this proposed research approach is to summarise, classify, and analyse the bending failure of a CFS beam based on numerical and experimental studies. A systematic literature review has been proposed to accomplish this goal. The entire SLR procedure is divided into three (3) stages as shown in figure 2.1.

1. Planning phase

- The systematic review methodology has been defined first in the planning phase, followed by the design of review questions.

2. Conducting Phase

- There are three distinct sub-processes. In the next subtopics, these subprocesses has been further explained.

3. Reporting Phase

- The reporting step entails documenting all of the SLR processes as well as data extraction and synthesis conclusions. It also responds to the follow-up questions posed in the first phase.

Figure 2.1: SLR procedure

The systematic review followed a well-defined protocol in which the parameters are explicitly stated before the review begins. It is an open search that can be replicated and reproduced across multiple databases. As a result, the current systematic review focuses on experimental and numerical research works that have looked at and analysed bending failures in CFS beams. During the review process, transparent and thorough database searches were conducted to ensure the acquisition of as many research as possible on bending failures in CFS beams to address the SLR issues.

2.2 Methodology Planning

There are the protocols of SLR have been used while conducting the systematic literature review on this topic.

2.2.1 Protocol of SLR

As indicated in Figure 2.2, the SLR process is carried out step by step. The protocol begins with the definition of the review questions. Following that, the search strategy is defined. The inclusion and exclusion criteria are then used to define the study's selection. The quality evaluation has been completed. Finally, data from primary studies is collected to help answer the review questions. The data extracted and synthesised in Chapter 4 is used in the analysis and discussion to reach a conclusion. The protocol lays out all of the processes that researchers must follow during the review in order to reduce threats to validity and neutralise author bias. The review methodology is one of the primary aspects that distinguishes SLR from typical literature reviews.

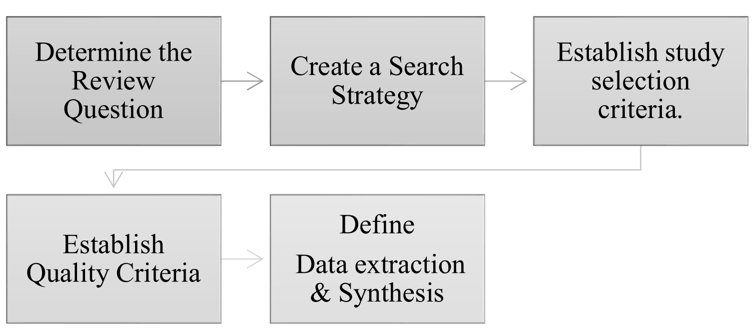

Figure 2.2: SLR Protocol

2.2.2 Definition of Review Question

According to Counsell (1997), p. 381, "the review question should be well-formulated, answerable, and focused." The review questions will specify which studies will be included, what type of search strategy will be used to identify relevant primary studies, and what data will be extracted from each study. A bad question will lead to a bad review. Furthermore, a systematic review is predicated on a predefined review topic and objectives. The review question should be defined at the start of the systematic literature review. A well-posed, answerable question is the foundation of a good systematic review. The question guides the review by stating which studies will be included, the search strategy for identifying relevant primary studies, and the data that must be extracted from each study.

2.3 Conducting SLR

There are several strategies used while conducting the systematic literature review on this topic.

2.3.1 Systematic Searching Strategy

This review work's relevant scholarly sources (previous works) are identified using systematic searching strategies. Despite the fact that there are numerous digital sources available, only SCIENCEDIRECT and SCOPUS were used. As a result, the specific search strings were used to accomplish that goal. The search strings used in this review study were created using the following technique and criteria.

1. Identification
   - The main keywords should be derived from the topics, review objectives, and review questions.
2. Determination
   - Find synonyms, related terms, and alternative terms for the primary keywords.
3. Checking
   - check the keywords used by the researchers in all relevant papers, then use them for the initial searches on the relevant databases.
4. Using the Boolean "OR," incorporate alternative spellings and synonyms.
5. Using the Boolean "AND" operator, connect the main terms.
6. Experiment with different search term combinations.

Referring to the steps mentioned above, the search string was defined as below:

(("bending failure" OR "local buckling" OR "local torsional") AND ("cold-formed steel") AND ("beam" OR "channel" OR "section"))

2.3.1(a) Identification

Identification is an SLR subprocess that is used to enrich the keywords associated with this study in order to diversify the search techniques and find more related and topic-focused articles. Otherwise, other potentially relevant articles may be overlooked by the database. The enriched keywords from the title and review questions are shown in Table 2.1.

Table 2.1: Identification of Keywords

Section	Main keywords	Enriched keywords
Tittle: Bending failure in cold formed steel beam : A Review	Cold-formed steel Bending Failure Beam	Cold-formed steel= CFS Bending failure= local distortional, buckling behavior, local buckling

		Beam= built-up beam, channel, section
RQ1: What is the type of failures of CFS beam when subjected to bending?	Failures Subjected bending	Failures = behavior, mode of failure, damages Subjected= exposed, experiencing, under Bending = local distortional, buckling, local buckling, twisting
RQ2: What are the factors that influence the bending failure in CFS beam?	Factor Influence Bending failure CFS beam	Factor= element, aspect, component Influence= affect, determine, govern Bending failure= local distortional, buckling behavior, local buckling CFS beam= CFS sections, channel, web
RQ3: What is the method used to investigate the bending failure in CFS beam?	Method Investigate Bending failure CFS beam	Method= procedure, technique, process Investigate= explore, look int

		Bending failure= local distortional, buckling behavior, local buckling CFS beam= CFS sections, channel, web

2.3.1(b) Screening

Screening is the second subprocess of SLR that was used to filter out the undesirable criteria of the articles and narrow the scope of searching to get the desired type of articles by including favourable criteria. All of the criteria should be established and understood prior to beginning the search. The filtering procedure is generally based on the timeline, publication type, and language, as shown in Table 2.2. Articles from the previous ten years were considered because the contents are assumed to be relevant to the current studies. The publication type also took into account review papers in order to keep up to date on the most recent existing review status of CFS. Following that, only English articles were considered in order to narrow the scope and avoid misinterpretation of the content in non-English articles. Finally, to eliminate unrelated subjects, the related subject area was included.

Table 2.2: Screening Criteria

Criteria	Inclusion	Exclusion
Timeline	2018-2022	Before 2017
Publication type	Review Papers, Research Articles, Journal	Conference proceeding, newspaper, book chapter

Language	English	Non-English
Subject Area	Engineering, Material Science, Chemistry, Structures	Physics & Astronomy, Computer Science

2.3.1(c) Create Searching Strings

The enriched keywords from Section 2.3.1(a) and the screening criteria set from Section 2.3.1(b) were used and applied in the development of the searching strings. Then, to begin the search, the strategies described in Section 2.3.1 were used. Table 2.3 shows the searching strings for the title, while Table 2.4 is the searching strings for RQ1, Table 2.5 is the searching strings for RQ2, and Table 2.6 is the searching strings for RQ3.

Table 2.3: Searching Strings Developed for Title

Database	Search string
Science direct	("buckling" OR ”bending” OR ”twisting”) AND ("cold-formed steel") AND ("beam" OR "channel" OR "section")
Scopus	TITLE-ABS-KEY(("buckling" OR ”bending” OR ”twisting”) AND ("cold-formed steel") AND ("beam" OR "channel" OR "section"))

Table 2.4: Searching Strings Developed for SLR.RQ1

Database	Search string
Science direct	(“behaviors” OR ”mode of failures”) AND (“cold-formed” OR ”CFS”) AND (“beam” OR “channel” OR “section”) AND (“bending” OR “buckling” OR “twisting”)

Scopus	TITLE-ABS-KEY(("buckling" OR ”bending” OR ”twisting”) AND ("cold-formed steel") AND ("beam" OR "channel" OR "section") AND (“bending” OR “buckling” OR “twisting”))

Table 2.5: Searching Strings Developed for SLR.RQ2

Database	Search string
Science direct	(“factor” OR “element” OR “component”) AND (“influence” OR ”affect” OR ”determine”) AND (“bending” OR “buckling” OR “twisting”) AND (“cold-formed steel”)
Scopus	TITLE-ABS-KEY((“factor” OR “element” OR “component”) AND (“influence” OR ”affect” OR ”determine”) AND (“bending” OR “buckling” OR “twisting”) AND (“cold-formed steel”))

Table 2.6: Searching Strings Developed for SLR.RQ3

Database	Search string
Science direct	(“method” OR “procedure” OR “process”) AND (“investigate” OR “explore”) AND (“bending” OR “buckling” OR “twisting”) AND (“cold-formed steel”)
Scopus	TITLE-ABS-KEY ((“method” OR “procedure” OR “process”) AND (“investigate” OR “explore”) AND (“bending” OR “buckling” OR “twisting”) AND (“cold-formed steel”))

2.3.1(d) Eligibility

Following the compilation of the selected sources, eligibility was determined. Typically, the eligibility of the retrieved articles were manually monitored to ensure that all of the remaining articles (after the screening process) meet the criteria. The title and abstract of the articles can be used to determine eligibility. If there is still no clear understanding of the relevance of the selected articles to the study, the content of the articles have been examined.

The PRISMA flow diagram (available at http://www.prisma-statement.org/) was used to show all procedures involved in systematic searching strategies, as shown in Figure 2.3. According to Figure 2.3, SCOPUS articles have less sources than SCIENCDIRECT articles, while papers addressing RQ1 and RQ3 (bending behavior of CFS and method used to detect the behavior) have more sources than publications addressing RQ2 (factor that influence the bending behavior of CFS).

The number of primary studies collected from various initial searches on digital libraries and manual searches was 3019. In the Screening phase, duplicate sources in SCOPUS and SCIENCEDIRECT were deleted using Mendeley Desktop software, and irrelevant articles were excluded by reading their title and abstract and applying inclusion and exclusion criteria modified from Khan et al. (2003), which are described below:

Inclusion criteria (IC):

- (IC1) The primary research proposes or employs a method to reflect the impact of fire on CFS sections.
- (IC2) If there were several studies on the same topic, the most complete and recent version of the study should be included. However, to comply with the rule set by the USM, School of Civil Engineering for the course EAA 492, a minimum

of 30 papers must be reviewed in SLR to meet the requirement in the marking rubrics. Thus, the past and most recent papers will be reviewed altogether.

Exclusion criteria (EC):

- (EC1) The primary study addresses the influence of fire on the criteria that other than buckling performance and lateral resistance of CFS.
- (EC2) The lack of sufficient details that described full methods of study whether numerical or experimental studies in addressing the review questions.

As a consequence of the IC and EC, 32 primary studies were chosen to be assessed further to ensure that they were eligible.

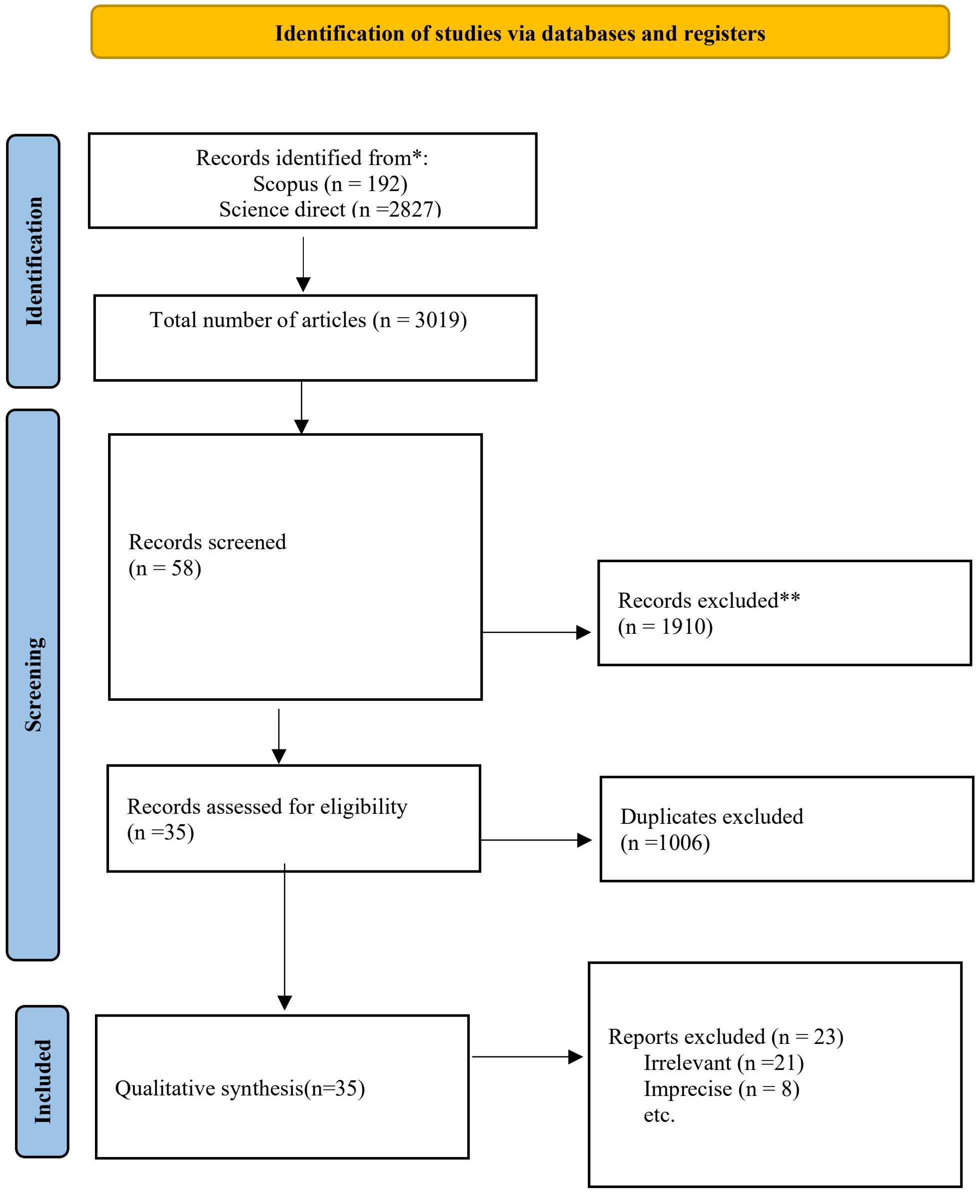

Figure 2.3: PRISMA Flow Diagram

2.3.2 Data Extraction and Synthesis

After the searching, collection, and quality assessment were completed, data from the 33 primary studies were extracted to answer the review questions outlined in Section 1.4. The extracted data from the primary studies, as well as additional information, will be displayed. Chapter 3 was cover this topic, and Chapter 4 was cover the review questions. The data will be extracted using the procedures outlined in Tables 2.7, 2.8, and 2.9. These tables show the relationship between data extraction questions and review questions that help with answers

The title, author year of publication, and publishing country (DE1.Q1, DE1.Q2, DE1.Q3, and DE1.Q4) were extracted for documentation purposes during data extraction for the descriptive data extraction form. Whereas, the type of publication, the publication outlet, the research objectives, the scope of the research, and a brief description of the research (DE1.Q4, DE1.Q5, DE1.Q6, DE1.Q7, DE1.Q8, and DE1.Q9) were to ensure the reliability of the review. Finally, the method of study (DE1.Q10) was identified to ensure the research method.

DE2.Q1, DE2.Q2, and DE2.Q3 are for documentation purposes only and are not used for data extraction of the experiment's analytical data. In contrast, the identified test method, main equipment, loading, design standards, and limitations (DE2.Q4, DE2.Q5, DE2.Q6, DE2.Q7, and DE2.Q11) were recorded to address and aid in the elaboration of the related review questions. During the brief findings, design parameters, and RQ related information was also for documentation purposes.

The aims of data extraction for numerical analytical data are the same as for experimental data. DE3.Q1, DE3.Q2, and DE3.Q3 are used for documentation as well as descriptive data extraction. In contrast, the identified test method, main equipment, loading, design standards, and limitations (DE3.Q4, DE3.Q5, DE3.Q6, DE3.Q7, and DE3.Q11) were recorded to address and aid in the elaboration of the related review questions. During the brief findings, design parameters, and RQ related information is also for documentation purposes. To ensure the efficiency, the data extraction was performed using an Excel spreadsheet. Finally, the findings were subjected to sanity checks, and any discrepancies were worked out collaboratively.

Table 2.7: Descriptive Data Extraction Details

	Descriptive Data Field	Related Concern/ Research Question
DE1.Q1	Paper title	Documentation
DE1.Q2	Author	Documentation
DE1.Q3	Year of publication	Documentation
DE1.Q4	Publishing country	Documentation
DE1.Q5	Type of publication (e.g., Journal, Conference, Generic etc.)	Reliability of Review
DE1.Q6	Publication outlet (Conference name, etc)	Reliability of Review
DE1.Q7	Research objectives	Reliability of Review
DE1.Q8	Research scope (beam)	Reliability of Review
DE1.Q9	Brief description	Reliability of Review
DE1.Q10	Method of study (Numerical or experimental)	RQ1, RQ2, RQ3

Table 2.8: Experimental Analytical Data Extraction Form

	Experimental Analytical Data Field (RQ1, RQ2)	Related Concern/ Research Question
DE2.Q1	Paper title	Documentation
DE2.Q2	Author	Documentation

DE2.Q3	Year of publication	Documentation
DE2.Q4	Test method	RQ1, RQ2, RQ3, RQ4
DE2.Q5	Main equipment	RQ1, RQ2, RQ3, RQ4
DE2.Q6	Design standards	RQ1, RQ2, RQ3, RQ4
DE2.Q7	Temperature	RQ1, RQ2, RQ3, RQ4
DE2.Q8	Brief finding	Documentation
DE2.Q9	Design parameter	Documentation
DE2.Q10	RQ (1 or 2)	Documentation
DE2.Q11	Limitation	RQ2, RQ3

Table 2.9: Numerical Analytical Data Extraction Form

	Experimental Analytical Data Field (RQ1, RQ2)	Related Concern/ Research Question
DE2.Q1	Paper title	Documentation
DE2.Q2	Author	Documentation
DE2.Q3	Year of publication	Documentation
DE2.Q4	Test method	RQ1, RQ2, RQ3
DE2.Q5	Type of software	RQ1, RQ2, RQ3
DE2.Q6	loading	RQ1, RQ2, RQ3
DE2.Q7	Design standards	RQ1, RQ2, RQ3
DE2.Q8	Brief finding	RQ1, RQ2, RQ3
DE2.Q9	Design parameter	Documentation
DE2.Q10	RQ (3)	Documentation
DE2.Q11	Limitation	RQ2, RQ3

2.4 Reporting the SLR

An excellent systematic analysis report should explain all of the steps and decisions made during the SLR process in simple terms. The information reported by researchers in SLR does not always accurately reflect their research methods (Devereaux et al., 2004). Furthermore, SLR reported in journals frequently underreport their search methods, validity evaluations of included research, and author conflicts of interest (Delaney et al., 2005; Golder et al., 2008; Roundtree et al., 2009). All SLR reports should follow a standard format to help readers find relevant details, improve SLR process documentation, and ensure accuracy in reporting. This study adheres to the PRISMA requirement (PRISMA, 2010), with the PRISMA checklist serving as the starting point for setting reporting criteria. The elements on the checklist are as follows:

1. A high-level summary.
2. For the general audience, the abstract was written.
3. A framework for analysis and a description of the study's logic chain.
4. The explanation behind the findings in different investigations.
5. Results of the qualitative synthesis.
6. Results are summarized in tables or graphics.
7. Evidence discrepancies.
8. Future research requirements

2.5 Summary

Finally, everything about SLR was covered in this chapter. The SLR protocol and its search strategies, in particular, have been discussed. The review results will be discussed further in the following chapters.

CHAPTER 3

DATA EXTRACTION AND SYNTHESIS

3.1 Introduction

This chapter was revealed the strategy for developing the framework of data extraction and synthesis in this chapter. As stated in 2.3.3, systematic techniques has been the primary approach to assisting the researcher in obtaining relevant data from the inclusion paper and reviewing it in accordance with its theme in order to answer the research question. Following that, the PRISMA checklist 2009 (PRISMA, 2015a) was used as an additional tool for the researcher to plan a generalizable, unbiased data extraction and synthesis methodology. The PRISMA 2009 checklist includes four items (items 10–13) for data extraction and three (items 14–16) for data synthesis (Appendix 1).

3.2 Data extraction

In order to help the readers understand this review about the bending failure and behavior of cold-formed steel beam, as well as its method to determine the behavior, an organized and well-planned review result is required, so systematic technique was used. To obtain comprehensive and important information from each inclusion paper, the two stages of data extraction were performed. Piloted extraction forms were used in the first stage to determine whether the data extracted is valid and sufficient for the synthesis in answering the review question (Liberati et al., 2009). Following that, the piloted forms was improvised using a deductive approach in accordance with their theme.

3.2.1 Identifying data to be extracted

Initially, the 35 included papers was read several times to get a sense of the overall picture of the data. Immersion serves the purpose of becoming more fully aware of the item that can be extracted and related to the review question. Important information was highlighted in each of the papers throughout the reading to prepare for discussions part.

3.2.2 Descriptive Data Extraction Method

General information is extracted for descriptive data to get a general idea of the articles. The descriptive data extraction form is shown in Table 3.1.

Table 3.1 : Descriptive data

No	Tittle of Publication, Author		Publishing Country	Type of Publication	Publication Outlet	Year	Reasearch Objective	Reasearch Scope	Brief Description	Methods
1	Bending-Induced Cross-Sectional Deformation of Cold-Formed Steel Channel- Section Beams	(Dai and He, 2021)	China	research article	Hindawi	2021	To describe the bending-induced cross sectional deformation in cold-formed steel channel- section beams when subjected to transverse bending	Beams	the nonlinear effect of cross-sectional deformation on the relationship between the overall bending curvature and applied moment is examined. A parametric study is also carried out to examine how the flange width, lip length, and thickness of the section affect the cross sectional deformation and corresponding nonlinear bending behavior of the beams. (Dai and He, 2021)	Numerical
2	A Study on the Bending and Seismic Performance of High Performance Cold Forming Composite Beam	(Choi et al., 2018)	Korea	Journal	Crossmark	2018	To evaluate the bending and seismic performance of the newly developed high-performance cold forming	Beams	As a result of the bending performance test, the bend ing moment of beam was increased stably depending on the depth and plate thickness of beam, and it is considered that the bending moment can be evaluated by the equation of a composite beam design.(Choi *et al.*, 2018)	Experimental