A SYSTEMATIC REVIEW: COMPRESSION FAILURE IN COLD-FORMED STEEL (CFS) COLUMN SECTIONS

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SCHOOL OF CIVIL ENGINEERING
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By

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Appendix A8

UNIVERSITI SAINS MALAYSIA

SCHOOL OF CIVIL ENGINEERING
ACADEMIC SESSION 2021/2022

FINAL YEAR PROJECT EAA492/6
DISSERTATION ENDORSEMENT FORM

Title: A Systematic Review: Compression Failure In Cold-formed Steel (CFS) Column Sections

Name of Student: Nur Farah Izzati Binti Mohd Tarmizi

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

Signature:

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Date : 10/8/2022

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Date : 10/8/2022

Approved by:

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(Signature of Examiner)

Name of Examiner : PROF. IR. DR. TAKSIAH A.MAJID

Date : 10/8/2022

Appendix A5

SCHOOL OF CIVIL ENGINEERING
ACADEMIC SESSION 2021/2022

FINAL YEAR PROJECT EAA492/6
FINAL DRAFT ENDORSEMENT FORM

Title : A Systematic Review: Compression Failure in Cold-formed Steel (CFS) Column Sections

I, Nur Farah Izzati Binti Mohd Tarmizi hereby

declare that I have checked and revised the whole draft of dissertation as required by my supervisor.

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Date: 16/7/2022

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ABSTRACT

This study presents the review on the compression failure of cold-formed steel (CFS) column sections and the method of conducting the study either experimentally or numerically. Compression failure is when the material itself yields or is crushed during a compression failure, not the entire column. When the axially loaded stress exceeds the allowed stress, shorter and broader columns typically fail under compression failure. An accurate prediction of the buckling behaviour and factors that are impacting the compression failure of CFS column sections was necessary due to the recent expansion of the use of CFS in industries and mid-rise structures. Although there were several research on buckling performance, they were not explicitly and properly explained. This research's goal is to give a systematic review of the literature on the compression failure of cold-formed steel (CFS) column sections. It also discusses possible study methods, such as experimental or numerical methods. In this review work, the compression failure of CFS column sections will be reviewed. From the studies, the factors that influenced the compression failure in CFS column sections have been discussed from the design parameter such as section properties, section geometry and additional materials. Then, several types and modes of compression failure have been discovered such as local, global and distortional buckling from the thirty-three research articles that have been reviewed.

ABSTRAK

Kajian ini membentangkan ulasan tentang kegagalan mampatan bahagian tiang keluli terbentuk sejuk (KTS) dan kaedah menjalankan kajian sama ada secara eksperimen atau numerik. Kegagalan mampatan ialah apabila bahan itu sendiri menghasilkan atau dihancurkan semasa kegagalan mampatan, bukan keseluruhan tiang. Apabila tegasan yang dimuatkan secara paksi melebihi tegasan yang dibenarkan, tiang yang lebih pendek dan lebih luas lazimnya gagal di bawah kegagalan mampatan. Ramalan yang tepat tentang tingkah laku lengkokan dan faktor yang memberi kesan kepada kegagalan mampatan bahagian lajur KTS adalah perlu disebabkan oleh pengembangan penggunaan KTS dalam industri dan struktur pertengahan baru-baru ini. Walaupun terdapat beberapa kajian tentang prestasi lengkokan, ia tidak dijelaskan dengan jelas dan betul. Matlamat penyelidikan ini adalah untuk memberikan tinjauan sistematik literatur mengenai kegagalan mampatan bahagian tiang keluli terbentuk sejuk (KTS). Ia juga membincangkan kaedah kajian yang mungkin, seperti kaedah eksperimen atau berangka. Dalam kerja semakan ini, kegagalan mampatan bahagian lajur KTS akan disemak. Daripada kajian, faktor-faktor yang mempengaruhi kegagalan mampatan dalam bahagian lajur CFS telah dibincangkan daripada parameter reka bentuk seperti sifat bahagian, geometri bahagian dan bahan tambahan. Kemudian, beberapa jenis dan mod kegagalan mampatan telah ditemui seperti lengkokan tempatan, global dan herotan daripada tiga puluh tiga artikel yang telah disemak.

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LIST OF ABBREVIATIONS

CFS	Cold-Formed Steel
SLR	Systematic Literature Review
RO	Review Objectives
RQ	Review Questions
LFRS	Lateral Loads Resisting System
QAC	Quality Assessment Criteria
DE	Data Extraction of a form
Q	Question onto the Information Related
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
UK	United Kingdom
RWS	Rijkswaterstaat
EC, EN	Eurocode
AS/NZS	Standard Australia and Standard New Zealand
NAS	North American Specifications
AISI	American Iron and Steel Institute
NBR	Brazilian Standard
ASCE	American Society of Civil Engineers
BS	British Standard
ISO	International Organization for Standardization
LVDTs	Linear Variable Displacement Transducers
LWTs	Linear Wire Transducers
ASTM	American Society for Testing Materials
LB	Local Buckling
GB	Global Buckling

TB	Torsional Buckling
LB+TB	Local-Torsional Buckling
FB	Flexural Buckling
FB+TB	Flexural-Torsional Buckling
FEA	Finite Element Analysis
FEM	Finite Element Method
PDEs	Partial Differential Equations
cFSM	Constrained Finite Strip Method
DSM	Direct Strength Method
USM	Universiti Sains Malaysia
SHS	Square Hollow Section
RHS	Rectangular Hollow Section
KBS	Keluli Berbentuk Sejuk

CHAPTER 1

INTRODUCTION

1.1 Background

There are two forms of structural steel used in building construction: hot-rolled steel shapes and cold-formed steel shapes. Cold-formed steel forms are made at room temperature, whereas hot-rolled steel shapes are formed at greater temperatures. Steel plate, sheet, or strip material is often used to make cold-formed steel structural components. The material is formed by either press-braking or cold roll-forming to create the appropriate shape throughout the production process. Corrugated steel roof and floor decks, steel wall panels, storage racks, and steel wall studs are all examples of cold-formed steel. Since the first flat sheets of steel were made by the steel mills over a century ago, they have been manufactured. In recent years, however, improved strength materials and a larger variety of structural applications have resulted in a substantial increase in cold-formed steel structural members compared to typical heavier hot-rolled steel structural elements.

The yield point and tensile strength are the two key qualities that distinguish carbon steel and high strength low alloy steel grades utilized for cold-formed steel products. Ductility, hardness, and weldability are other essential qualities. Steels usually used for cold forming have yield points ranging from 33 to 55 ksi (230 to 380 MPa) and may be higher. Because of the way tensile strength and ductility relate to formability, as well as the local deformation needs of bolted and other forms of connections, they are crucial. The tensile strength of members with bolted connections or that may be susceptible to significant stress concentrations due to particular design must typically be considered. Cold-formed steels typically have a tensile strength to yield a strength ratio of 1.2 to 1.8. Steels with a lower ratio, on the other hand, can be employed in specialized applications.

Although many people think of cold-formed steel framing as a "new" building material, it has been utilized in North America for more than a century. The use of cold-formed steel members for building construction began in the 1850s in both the United States and England. The application was mostly experimental, and it was confined to a few basic structures. However, there is a lack of well-documented and comprehensive study on compression failure in Cold-Formed Steel (CFS) sections. When the compressive axial force applied to a compression member, such as a column or a brace, causes the element to buckle or become overstressed, compression failures occur. Column and brace members exposed to significant compressive pressures, similar to beams, may buckle. Compression failure or buckling of the member occurs when the compression load occurring on the axis of the member is high (greater than the load for which it was designed). In concentric compression, three failure mechanisms for CFS members were studied. Local buckling, torsional or flexural-torsional buckling, and distortional buckling are the three types of buckling. When a failure is triggered by buckling of an element in a specific local region of the member, it is known as local buckling. Torsional buckling, also known as flexural torsional buckling, is caused by lateral displacement, which causes the member to twist and bend. When the flanges rotate around the web connection, the flange is displaced from its original location, causing distortion.

1.2 Problem Statement

Due to its high strength-to-weight ratio, cheap manufacturing costs, and exceptional fabrication adaptability, cold-formed steel (CFS) sections have grown more popular in the construction industry over the last several decades, particularly in low-rise residential and industrial structures (Huang et al.,2020). Most studies on the buckling behaviour of CFS channel sections under axial compression were found in the literature. The factors contributed to compression failure of CFS column sections and types of failure will be figure out using a systematic literature review method based on previous research and experimental and numerical data.

1.3 Systematic Literature Review (SLR): Review Objectives

The objectives of this study are as follows:

Table 1.1: The objectives of the study

No.	Review Objectives
RO1	To examine the factor influenced the compression failure in Cold-Formed Steel (CFS) column sections
RO2	To identify the types and modes of compression failures in cold-formed steel column sections

1.4 Systematic Literature Review (SLR): Review Questions

The SLR includes the following review questions as shown in Table 1.2 below:

Table 1.2: Review Questions for the Study

No.	Review Questions
RQ1	What are the factors that influenced the compression failure in cold-formed steel (CFS) column sections?
RQ2	How experimental studies have been conducted to examine the compression failures in cold-formed steel (CFS) column sections?
RQ3	What kind of numerical studies conducted to examine the compression failures in cold-formed steel (CFS) column sections?
RQ4	How the experimental studies have been conducted in examining the types and modes of compression failures in cold-formed steel column sections?

1.5 Contribution and Importance

When compared to hot rolled steel, CFS provides a higher strength-to-weight ratio, greater ductility, and faster production and installation, as stated by Samiee et al. (2021), which according to the research that has been conducted (Craveiro, 2015; Gunalan, 2011; Kolarkar, 2011; Niari et al., 2015). Cold-formed steel (CFS) parts are becoming more popular as load-bearing members in construction, particularly in seismic areas. In severe earthquakes, design standards often enable more traditional hot-rolled steel and concrete building structures to exceed their elastic limits, making aspects like ductility and energy dissipation crucial (Ye, Mojtabaei and Hajirasouliha, 2018).

1.6 Overall Thesis Structure

This thesis is divided into five chapters to meet the goals. This study's first chapter will serve as an introduction. The comprehensive literature review procedure for finding relevant scholarly sources of the impact of fire on lateral resistance and buckling performance of CFS for review works will be provided in Chapter 2. In Chapter 3, a systematic literature review (SLR) based on more than 30 previous research publications evaluates and analyses relevant and current studies to offer a better understanding of the research. SLR results for each of the four review questions (in Section 1.4) will be published and discussed in Chapter 4. The findings will be used to form a conclusion and a suggestion in Chapter 5.

1.7 Limitations

The limitation for this review is for compression failure in cold-formed steel (CFS) sections in column only.

CHAPTER 2

SYSTEMATIC LITERATURE REVIEW (SLR): A METHODOLOGY

2.1 Introduction to the Systematic Literature Review (SLR)

Based on numerical and experimental investigations, the fundamental goal of this suggested research approach is to summarise, categorise, and analyse compression failure in cold-formed steel (CFS) sections. A systematic literature review has been proposed to attain this purpose. A systematic review is a literature review that aims to find, analyse, and synthesise the best accessible evidence (also known as primary scholarly sources) in order to give relevant and evidence-based responses to particular review questions (Boland et al., 2017). Before gathering evidence, the systematic review must strictly adhere to pre-defined and clear protocols. SLR can identify, assessing, and choosing research to answer a specific question (Dewey and Drahota, 2016). The seven primary values of SLRs are transparency, clarity, integration, focus, equality, accessibility, and coverage according to Pittway (2008). Before the review begins, the systematic analysis should follow a well-defined methodology with the parameters well established. It's a transparent search that can be duplicated and copied across databases.

As a result, the current systematic review focuses on experimental and numerical research studies that have looked at and analysed compression failure in cold-formed steel (CFS) sections. During the review process, transparent and extensive database searches were conducted to guarantee the collection of as many papers as possible on the effect of fire on both categories to answer the SLR questions.

2.2 Planning of SLR

2.2.1 SLR Protocol

The protocol is an important part of the systematic literature review (SLR) process. The protocol lays out all of the steps (sub-processes) that students must follow throughout a review in order to eliminate author bias. One of the primary features that distinguishes SLRs from traditional literature reviews is the review methodology. The procedure begins with the specification of the review questions, followed by a description of the search method to be used. In the searching technique, the inclusion and exclusion criteria are specified to give a systematic means of picking among recognised primary research. The quality of the identified studies (articles) is next evaluated. The data items retrieved from the primary studies are then identified to assist in answering the review questions. In Chapter 4, the data that has been extracted and synthesised is used in the analysis and discussion to reach a conclusion.

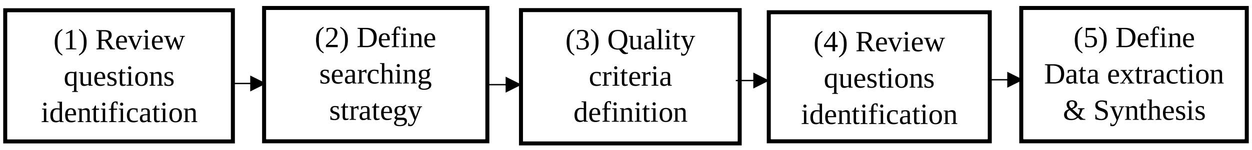

Figure 2.1: SLR Review Protocol

2.2.2 Formulation of Review Questions

'The foundation of a successful systematic review is a well-formulated, answered question.' The question directs the review by determining which studies will be included, what search method should be used to locate relevant primary research, and what data should be gathered from each study. If you ask a terrible question, you'll receive a bad answer." (Counsell, 1997). A systematic review is one that follows a pre-determined review subject and objectives. It's a good idea to do some scoping searches in a database to see if there are any reviews on your topic and if it's an original one. The review questions may then be created from there. Systematic reviews can address a wide range of issues, but they must be concise, targeted, well-formulated, and responsive. Finally, several components of the review process, such as setting eligibility criteria, searching for research, gathering data from included studies, and presenting findings, will be guided by well-formulated questions (Cochrane Handbook, 2020).

Further, not many reviews have been conducted on cold-formed steel (CFS) member in Malaysia. As a result, by conducting a systematic analysis of the literature, this review work focuses on investigating the current empirical and numerical studies on compression failure of CFS column sections.

2.3 Conducting the SLR

2.3.1 Systematic Searching Strategies

The relevant academic materials (previous works) for this review work were identified using systematic searching procedures. As a result, the exact search strings were employed to accomplish that purpose. The search strings utilised in this review research were created using the following approach and criteria.

2.3.2 Identification

The initial step in the procedure is identification of the core keywords and look for synonyms, related terms, and variations. Its goal is to give the selected database more possibilities for searching for similar articles to examine. First, the review objectives and review questions are used to determine the main keywords. The keyword enrichment procedure is then carried out using an online thesaurus, keywords from previous studies, keywords offered by the database, and keywords supplied by experts.

Table 2.1: The enriched keywords from the title and review questions.

Section	Main keywords	Enriched keywords
Title: Compression failure in cold-formed steel (CFS) column sections: A review	Compression failure Column Cold-formed steel sections	Compression failure = structure buckles or collapses Column = compression member Cold-formed steel = CFS

RQ1: What are the factors that influenced the compression failure in cold-formed steel (CFS) column sections?	Factors Influenced Compression failure Column Cold-formed steel sections	Factors = circumstance, fact Influence = effect, impact, repercussion, significant Compression failure = structure buckles or collapses Column = compression member Cold-formed steel = CFS
RQ2: How experimental studies have been conducted to examine the compression failures in cold-formed steel (CFS) column sections?	Experimental studies Examine Compression failures Column Cold-formed steel sections	Experimental = experiment, test Examine = inspect Compression failure = structure buckles or collapses Column = compression member Cold-formed steel = CFS
RQ3: What kind of numerical studies conducted to examine the compression failures in cold-formed steel (CFS) column sections?	Numerical Examine Compression failures Column Cold-formed steel sections	Numerical = Modelling, mathematical Examine = inspect Compression failure = structure buckles or collapses Column = compression member Cold-formed steel = CFS
RQ4: How the experimental studies have been conducted in examining the types and modes of compression failures in cold-formed steel column sections?	Experimental Examining Types and modes Compression failures Column Cold-formed steel sections	Experimental = experiment, test Examine = inspect Types = category, classification Modes = way, method

		Compression failure = structure buckles or collapses Column = compression member Cold-formed steel = CFS

The databases selected to search the related articles and documents for the review:

i. Leading database: Scopus, Science Direct

ii. Supporting databases: NA

2.3.3 Screening

The inclusion and exclusion criteria for the articles to be reviewed are determined during the screening phase of the systematic searching strategy procedure. The inclusion and exclusion criteria must be applied to all of the recognised items (in the identification sub-process). The sorting mechanism present in the selected databases can be used to perform this screening automatically. Timeline, publishing genres, and language are the typical criteria for inclusion and exclusion in the inclusion and exclusion setup. As illustrated in Table 2.2, the filtering procedure is generally based on the timeline, publishing type and language.

Table 2.2: Screening Criteria

Criteria	Inclusion	Exclusion
Timeline	2017-2022	Before 2017
Publication Type	Review Papers, Research Articles, Journal	Conference proceeding, newspaper, books, chapter in book
Language	English	Non-English

2.3.4 Develop Searching Strings

In developing the searching strings, the enriched keywords from Section 2.3.1.1, and the screening criteria set from Section 2.3.1.2 were used and applied. Next, follow the searching strategies in Section 2.3.1 to initiate the searching. For the results, Table 2.3 shows the searching strings for the title, Table 2.4 is for the RQ1, Table 2.5 is for RQ2, whereas Table 2.6 is for RQ3, then Table 2.7 is for RQ4.

Table 2.3: Searching Strings Developed for Title

Database	Search String
Scopus	TITLE-ABS-KEY(("compression failure" OR "structure buckles" OR "structure collapses") AND ("column" OR "compression member")AND("cold-formed steel"))
Science Direct	("compression failure" OR "structure buckles" OR "structure collapses") AND ("column" OR "compression member") AND ("cold-formed steel"))

Table 2.4: Searching Strings Developed for SLR.RQ1

Database	Search String
Scopus	TITLE-ABS-KEY(("factors" OR "circumstance" OR "fact") AND ("influence" OR "effect" OR "impact" OR "repercussion" OR "significant") AND ("compression failure" OR "structure buckles" OR "structure collapses") AND ("column" OR "compression member") AND ("cold-formed steel"))
Science Direct	("factors" OR "circumstance") AND ("influence" OR "effect") AND ("compression failure" OR "structure buckles") AND ("column" OR "compression member") AND ("cold-formed steel"))

Table 2.5: Searching Strings Developed for SLR.RQ2

Database	Search String
Scopus	TITLE-ABS-KEY(("experimental" OR "experiment" OR "test") AND ("examine" OR "inspect") AND ("compression failure" OR "structure buckles" OR "structure collapses") AND ("column" OR "compression member") AND ("cold-formed steel"))
Science Direct	("experimental" OR "experiment") AND ("examine" OR "inspect") AND ("compression failure" OR "structure buckles") AND ("column" OR "compression member") AND ("cold-formed steel"))

Table 2.6: Searching Strings Developed for SLR.RQ3

Database	Search String
Scopus	TITLE-ABS-KEY(("numerical" OR "modelling" OR "mathematical") AND ("examine" OR "inspect") AND ("compression failure" OR "structure buckles" OR "structure collapses") AND ("column" OR "compression member") AND ("cold-formed steel"))
Science Direct	("numerical" OR "modelling") AND ("examine" OR "inspect") AND ("compression failure" OR "structure buckles") AND ("column" OR "compression member") AND ("cold-formed steel"))

Table 2.7: Searching Strings Developed for SLR.RQ4

Database	Search String
Scopus	TITLE-ABS-KEY(("experimental" OR "experiment" OR "test") AND ("examine" OR "inspect") AND ("types" OR "category" OR "classification") AND ("modes" OR "ways" OR "method") AND ("compression failure" OR "structure buckles" OR "structure collapses") AND ("column" OR "compression member") AND ("cold-formed steel"))

Science Direct	("experimental") AND ("examine" OR "inspect") AND ("types" OR "category") AND ("modes") AND ("compression failure") AND ("column") AND ("cold-formed steel"))

2.3.5 Eligibility

The final sub-step is eligibility, in which the authors manually review the retrieved articles to ensure that all of the remaining articles (after the screening phase) meet the requirements. This may be accomplished simply reading the article's title and abstract. If the relevance of the discovered articles to the research is still unclear, the substance of the articles should be reviewed. The quality evaluation can also be done at this stage to finalise the articles that will be included in the review process. The student examines each included full-text article using suitable quality assessment criteria during the quality assessment procedure. The criteria can be created using the review goals or review questions as a starting point.

All the processes conducted must be reported (in the Reporting phase) later. All the articles retrieved from the identification to the screening and lastly in the eligibility should be adequately recorded. It is suggested that the number of articles retrieved is recorded using PRISMA flow diagram (available at http://www.prisma-statement.org/) as shown in Figure 2.2.

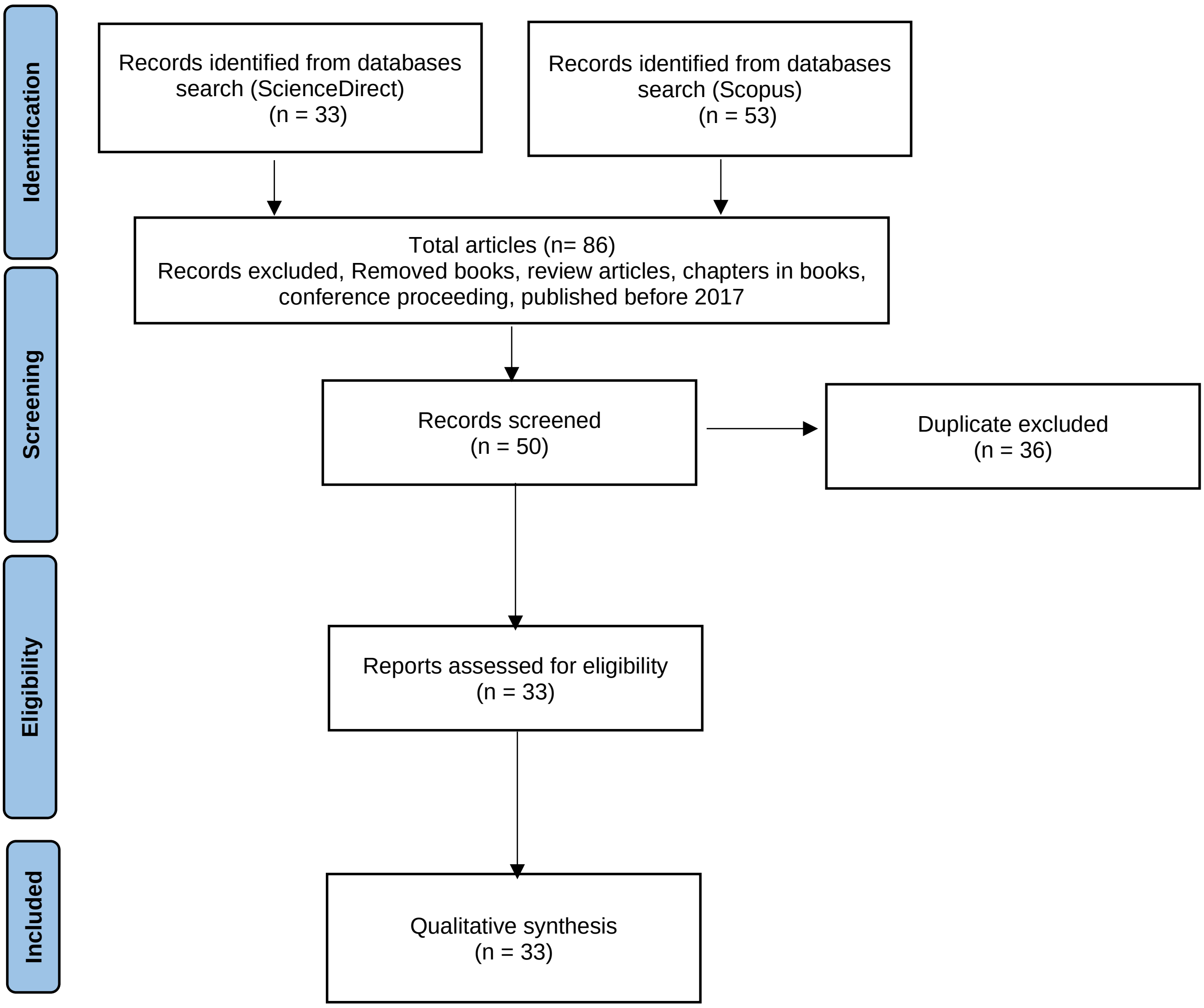

Figure 2.2: PRISMA Flow Diagram

CHAPTER 3

DATA EXTRACTION AND SYNTHESIS

3.1 Introduction

The literature has covered a variety of data gathering and synthesis/analysis frameworks and approaches, but the most utilised are non-meta-analysis (qualitative) and meta-analysis (quantitative). A summary of findings table are created for a non-meta-analysis. A meta-analysis, on the other hand, necessitates the pooling of data as well as specific statistical analysis. Qualitative synthesis is a technique used to collect, examine, and analyse non-numerical data, sometimes referred to as qualitative data, such as the results of studies. Any descriptive and non-numerical data, such as video, photography, or audio recordings, can be used as qualitative data. Quantitative synthesis, on the other hand, is the process of gathering and analysing numerical data to explain, predict, or control variables of interest. Despite recent advances in machine learning models for automating data extraction in systematic reviews, data extraction remains mostly human.

3.2 Data Extraction

The procedure of reading the whole text of each article chosen for inclusion in the study and extracting the pertinent data is known as data extraction. There are 33 articles in this review that must be read in order to extract the relevant information and combine it in a tabular style. Endnotes, a data management programme, is needed to read the complete text of the articles, and the highlighting tool is required to highlight key information before filling out the form. A standardised extraction form with various data fields is also constructed in Microsoft Excel to ensure that the information collected is impartial and error-free. The extracted data was organised in the field, and the articles will be compared side by side.

3.2 Data Extraction Target

The details or information are extracted and recorded into an Excel Spreadsheet of table forms for further analysis. This section is discussing the method of conducting the data extraction.

3.2.1 Descriptive Data Extraction Method

The generic information is extracted for descriptive data so that readers may get a basic impression of the articles. Table 3.1 shows the descriptive data extraction form. As a result, the following details are retrieved and accompanied by their justifications:

i. Title of publication with authors- To introduce and expose the sort of research that was done in the paper.

ii. Research objective – To introduce the purpose of the study whereby it should be relevant to our study.

iii. Research scope – To differentiate the type of CFS section to be studied in the article.

iv. Brief description – To briefly explain the whole concept of research which should be relevant to our research as well.

v. Methods (Experimental or Numerical) –To distinguish the methods conducted in the research to aid in data synthesis later.

3.2.2 Analytical Data Extraction Method on Experimental Studies

The outcomes and conducting techniques for analytical data on experimental research are retrieved and given in Table 3.2. More information on the articles may be found in the analytical data. As a result, the following details, together with their accompanying justifications, have been extracted:

i. Title of publication with authors – To introduce and expose the type of study conducted in the article.
ii. Type of method – To present the experimental methods. There are two main types of method of experimenting mainly steady-state test and transient state test.
iii. Description of method – To brief the procedure of the experiment carried out.
iv. Design Standards – To reveal the reference of standard and code used in data analysis.
v. Brief findings – To present the overall discovery or knowledge from the experiment conducted.
vi. Design parameter – To present the factors that are considered in the experiment.
vii. RQ related – To reveal which review question each of the study related to, whereby the review questions should be focused on experimental results.
viii. Limitations – To list out the conditions of the experiment

3.2.3 Analytical Data Extraction Method on Numerical Studies

The outcomes and conducting procedures for analytical data on numerical studies are retrieved and given, which provides readers with additional specifics from the publications. As a result, the following details, together with their accompanying justifications, have been extracted:

i. Title of publication with the author – To introduce and expose the type of study conducted in the article.
ii. Type of method – To present the numerical methods. There are several types of method/analysis software to conduct the numerical study. The most used tool is ABAQUS, the details will be discussed later.
iii. Design standards – To reveal the reference of standard and code used in data analysis
iv. Brief findings – To present the overall discovery or knowledge from the modelling conducted
v. Design parameter – To present the factors that are considered in the experiment are listed out.
vi. RQ related – To reveal which review question each of the study related to, whereby the review questions should be focused on numerical results.
vii. Limitations – To list out the conditions when modelling

3.3 Data Extraction Results

3.3.1 Descriptive Data Table Form

Table 3.1 is showing the descriptive data extraction from all the 33 schorlarly sources.

Table 3.1: Descriptive Data

No	Title of Publication, Author		Year	Types of publication	Publication outlet	Research objectives	Research scope	Brief description	Methods (experimental/ numerical)
1	Axial compression behaviour of cruciform cold-formed steel built-up columns: Shape optimization and experimental study	(Chen *et al.*, 2022)	2022	Journal	Journal of Building Engineering	To examine the performance of cruciform CFS built-up columns under axial compression.	Lipped channel	The cruciform CFS built-up cross sections are formed through four identical multiroll lipped channels connected at their webs with high-strength bolts and filler plates. An optimization algorithm is primarily proposed that integrates sequential quadratic mathematical programming methods and finite strip analysis.	Experimental
2	Experiments and numerical predictions of cold-formed steel members with web perforations under combined compression and minor axis bending	(Ren *et al.*, 2022)	2022	Journal	Engineering Structures	To investigate the effect of perforations on the buckling behaviour and the strength of CFS members and	Cold-formed steel members with web perforations	Two typical load–displacement curves corresponding to two failure modes, i.e., Failure mode I – Distortional-flexural buckling interaction (DB + FB) and Failure mode II– Distortional-flexural torsional buckling interaction (DB + FTB) were derived from the tests	Experimental and Numerical

No	Title of Publication, Author		Year	Types of publication	Publication outlet	Research objectives	Research scope	Brief description	Methods (experimental/ numerical)
3	Experimental and numerical investigation on cold-formed steel built-up section pin-ended columns	(Li and Young, 2022b)	2022	Journal	Thin-Walled Structures	To examine the buckling behaviour and loading capacity of cold-formed steel (CFS) built-up section members subjected to axial compression	folded-flange channels	Failure modes with the interaction of outward distortional buckling and overall flexural buckling (D+F) as well as the interaction of local buckling at overlapped plates, inward distortional buckling at intermediate stiffener and overall flexural buckling (L+D+F), which were found for the specimens in the pin-ended column tests, respectively, are both well predicted by the FE analyses	Experimental and Numerical
4	Buckling resistance of concrete-filled cold-formed steel (CF-CFS) built-up short columns under compression	(Rahnavard *et al.*, 2022)	2022	Journal	Thin-Walled Structures	To investigate the compressive behavior of the presented CF-CFS built-up sections including load-bearing capacity, and buckling modes, understanding the contribution of concrete mitigating local buckling phenomena.	Lipped Channel	In terms of deformation and load bearing capability, the findings obtained using experimental testing and FE models were found to be quite close. As a result, these methodologies for finite element models may be employed as a dependable tool for future parametric studies. More variables, such as fastener spacing, b/t ratio, steel section and concrete-filled contribution to composite column capacity, and composite column slenderness impacts, will be examined further.	Experimental and Numerical

No	Title of Publication, Author		Year	Types of publication	Publication outlet	Research objectives	Research scope	Brief description	Methods (experimental/ numerical)
5	Compression tests of thin-walled cold-formed steel columns with Σ-shaped sections and patterned perforations distributed along the length	(Zhang and Alam, 2022)	2022	Journal	Thin-Walled Structures	To investigate the thin-walled roll-formed steel members with three distinct -shaped sections and six different lengths were compressed in this investigation.	Perforated CFS members (roll-formed sections)	This study discusses the axial strengths and stiffnesses of the columns, as well as failure mechanisms and structural reactions under compression. The DSM's parameters for calculating the axial strengths of these columns were then established, and the findings are also presented in this work. Finally, the evaluated axial strengths of the columns were used to assess the DSM's correctness. The DSM was shown to be unable to effectively predict the axial strengths of the columns, and these estimations were found to be too unconservative.	Experimental
6	Experimental tests on built-up cold-formed steel section laced compression members	(Ramzy, Dabaon and El-Boghdadi, 2022)	2022	Journal	Thin-Walled Structures	To present new experimental results using cold-formed steel laced compression members that have been built up.	Laced members	Two longitudinal cold-formed carbon steel channels (chords) were inserted back-to-back with an internal gap and joined utilising end batten plates and two parallel planes of single lacing systems in the built-up laced test specimens. Built-up laced members with comparable lengths but different back-to-back gap distances were used in the compression testing.	Experimental

No	Title of Publication, Author		Year	Types of publication	Publication outlet	Research objectives	Research scope	Brief description	Methods (experimental/ numerical)
7	Experimental investigation on the axial compression behavior of cold-formed steel triple-limbs built-up columns with half open section	(Sang *et al.*, 2022)	2022	Journal	Thin-Walled Structures	To explore the isolated shear performance of the screws used in the built-up columns.	Lipped channel	Single shear screwed connection tests were utilised to study the isolated shear performance of the screws used in the built-up columns. Pure global, distortional, and local buckling were observed to fail the G type, D type, and L type triple-limbs built-up columns, respectively, and the longitudinal spacing of the screws did not appear to affect the occurrence of the failure mechanism but could affect the specimen's ultimate strength.	Experimental
8	Optimization design of high-strength cold-formed steel stiffened lipped channel columns under axial compression	(Wang *et al.*, 2022)	2022	Journal	Structures	To verify the final optimization results by multiple optimization methods and investigate the variation trend among different prediction methods of CFS column load-carrying capacity	Lipped channels	Based on the theoretical load-carrying capacity estimate, a software was built to pick many suitable portions with high efficiency. Then, on the selected sections, finite element analysis and loading tests were performed, and the section with the maximum load-carrying capacity was judged to be the ideal section. The findings show that the variation patterns in load-carrying ability of members with various section sizes derived by theoretical calculation, finite element modelling, and loading tests were consistent.	Experimental and Numerical

No	Title of Publication, Author		Year	Types of publication	Publication outlet	Research objectives	Research scope	Brief description	Methods (experimental/ numerical)
9	Distortional buckling behavior of cold-formed steel built-up closed section columns	(Li, Zhou, Zhang, *et al.*, 2021)	2021	Journal	Thin-Walled Structures	To investigate the distortional buckling behavior of cold-formed steel (CFS) built-up closed section column	C-section, U-section, and built-up closed section	Under concentric axial compression, 12 C-section, 12 U-section, and 24 built-up closed section columns with self-drilling screws at their flanges were tested. The experimental members' distortional buckling behaviour and mechanical characteristics were explored, as well as their buckling modes and failure states. Models based on finite elements were created and confirmed.	Experimental and Numerical
10	Experimental investigation and design of cold-formed steel U-section columns with the local and global interactive buckling	(Li, Zhou, Li, *et al.*, 2021)	2021	Journal	Structures	To propose a design method for determining and designing cold-formed steel (CFS) U-section columns with the local and global (LG) interactive buckling.	U-section	A finite element model (FEM) was created to recreate experimental specimens and compare the findings to those of the experiment. A numerical simulation was also used to examine the width-to-height ratio, which is a significant parameter affecting the buckling modes and ultimate capacity of CFS U-section columns. Finally, a technique for determining the ultimate capacity of CFS U-section columns was developed based on the experimental and numerical results.	Experimental and Numerical