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Literature Review – Behaviour of Cold Formed Z Purlins with Sag Rods in PEBs

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***Abstract:* -- Cold formed steel is widely used in Pre-engineered buildings. It has gained popularity for its unique features of lightweight, better and standard connections, faster execution, etc. However, larger variations in the moment of inertias with respect to X and Y axis have led to distortional buckling in the members. Cold formed purlins have depths 100 times to that of its thicknesses. This has promoted lateral torsional buckling in the member for the unbraced length of the purlins. Use of sag rods is a widely adopted technique to curb the lateral torsional buckling in the member. This paper discusses a detailed review of the literature on deformations in cold formed Zed profiles, their comparisons and conclusions. The data generated through the literature survey will help to generate better and well-defined configurations of Z purlins and stable models for analysis.**

***Keywords*: - PEBs (Pre-Engineered buildings), CFS (Cold formed sections), FE (Finite element), FEA (Finite element analysis), UDL (Uniformly distributed load).**

I. INTRODUCTION

[1] Literature survey showed major research towards local and distortional buckling of cold formed Zed profiles under the action of wind loads. [1]–[3]Unbraced bottom flange of the purlins is of major interest. Cold formed steel is used for roof diaphragms to achieve optimized sections and economy. [3]–[5]Analysis and comparisons has been performed on Z purlins using software tools viz., ANSYS, ABACUS, CIVILFEM, etc. It has been observed that Z profiles are more suitable sections in all parameters of design considerations. [6]Reduced bending moment coefficients can be used in case of Z purlins as the overlapping of the purlins encounters the moment generated. Sag rods are used to control the effect of lateral torsional buckling in Z purlins. [2]Distortional buckling is an important factor leading to the failure of the roof diaphragms.

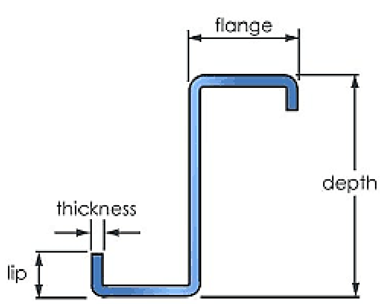

Fig. 1 Typical Z Profile

II. LITERATURE REVIEW

AVP Manoj. et. al. (2017)

[1]AVP Manoj investigated Flexural behaviour of cold formed 'Z' and 'HAT' sections. Evaluation has been carried out using ANSYS. In the analytical work, four sections were loaded vertically while the lateral deflection was unrestrained to allow flexural buckling. The members are of length 1500mm each. Major comparison was between sections with lips and without lips of Zed and Hat profiles of CFS.

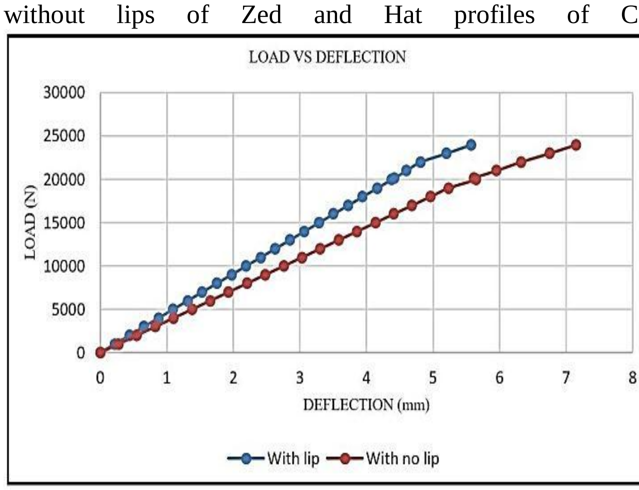

Fig. 2 [1]Load vs. Deflection Curve for Z Profiles

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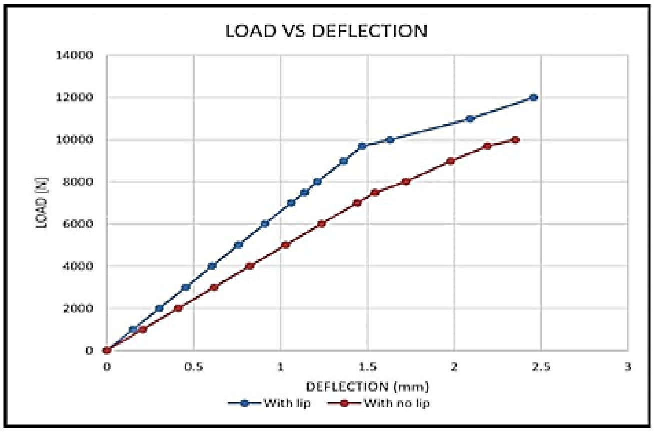

Fig. 3 [1]Load vs. Deflection Curve for HAT Profiles

Table I [1] Load vs. Deflection Curve for HAT Profiles

Profiles		Length (mm)	Load (KN)	Moment capacity (KN-m)	Deflection (mm)
Zed	Without lips	1500	18.16	4.54	4.96
	With lips	1500	20.16	5.04	4.41
Hat	Without lips	1500	7.5	1.87	1.54
	With lips	1500	9.7	2.42	1.47

From Fig. 2, Fig. 3 and Table I, the ultimate load carrying capacity of cold formed Z profiles with lips was 11% higher than that of cold formed Z profiles without lips. Similarly, the ultimate load carrying capacity of cold formed HAT sections with lips was 29% higher than that of cold formed HAT profiles without lips.

2. AHF Neto, et.al. (2016)

[2]Alomir aimed to analyze the strength and stiffness of semi-continuous cold-formed steel purlins subjected to flexure. A series of nine cold formed steel Z sections with sleeved and overlapped bolted connections were tested in bending. Two different Z sections were tested with similar shape dimensions but different thicknesses and configurations.

Table II [2] Various Configurations of Specimens Tested

SR	ACTUAL SPECIMEN	CONNECTION DETAILS
1	Z1 – C	Continuous Specimen
2	Z1 – L5	Sleeved Connection Length 1036 mm
3	Z1 – T5	Overlapped Connection Length 1036 mm
4	Z1 – T11	Overlapped Connection length 2200 mm
5	Z1 – L5P	Sleeved Connection Length 1036 mm
6	Z2 – C	Continuous Specimen
7	Z2 – L	Sleeved Connection
8	Z2 – T5	Overlapped Connection Length 1036 mm
9	Z2 – T11	Overlapped Connection Length 2200 mm

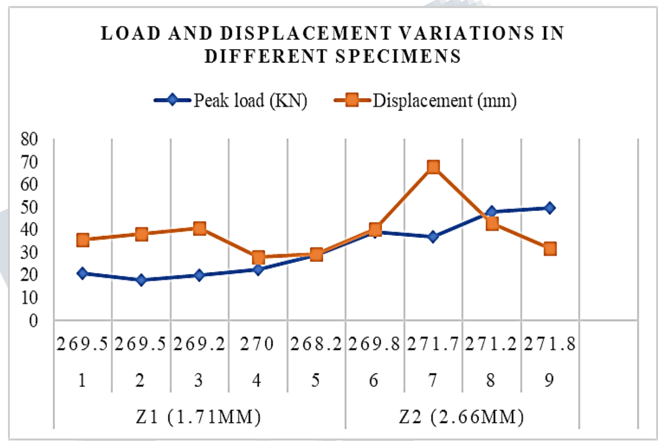

Fig. 4 [2] Load & Displacement Variations in Different Specimens

From Fig. 4, Alomir Neto concluded that Profiles with slightly higher thicknesses possess higher load carrying capacity with lesser deflections comparing the load to deflection ratios.

Table III [2] Load & Displacement Variations

Profile	Specimen	Depth (mm) h	Peak Load (KN)	Displacement (mm)
Z1 (THK 1.71MM)	1	269.5	20.6	35.6
	2	269.5	17.7	38.1
	3	269.2	19.6	40.6
	4	270.0	22.2	27.8
	5	268.2	28.8	29.3
Z2 (THK 2.66MM)	6	269.8	38.9	40.3
	7	271.7	36.8	67.9
	8	271.2	48.0	42.7
	9	271.8	49.5	31.7

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From Table III the Z profile with maximum load carrying capacity is specimen 9 i.e., Z profile of thickness 2.66 mm with overlapped connection length of 2200mm. the Z profile with minimum displacement is specimen 4 i.e., Z profile of thickness 1.7mm with the overlapped connection of 2200mm.

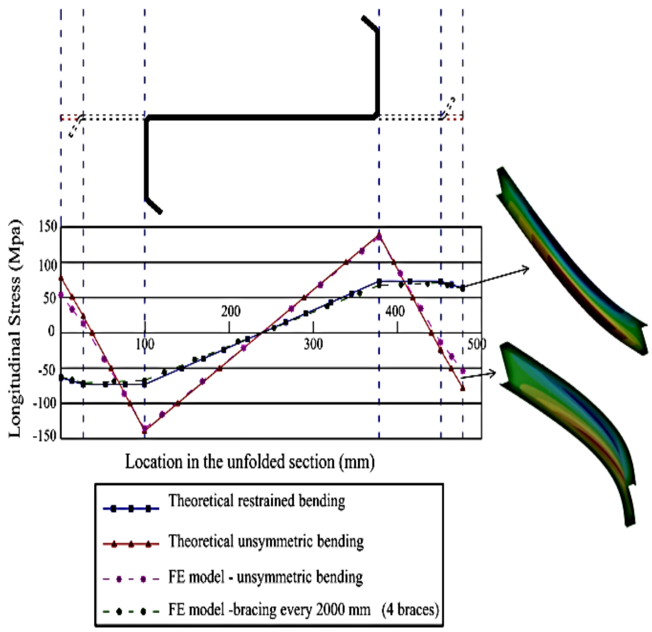

Fig. 5 [2]Graph Showing Theoretical & Experimental of Bending Stresses in Single Z Profile

From Fig. 5, Alomir concluded that purlins with bracing systems give lesser and equal distribution of bending stresses comparatively. For Z2 profiles while testing, only the sleeve buckled and no local buckling was observed. At peak load, the vertical displacement of the sleeved connection is 10% higher than for continuous purlin in thinner section (Z1) and 68% higher for thicker sections (Z2). For longer connection length, the specimens failed in distortional buckling. In thicker sections (Z2) there is the only slight increase (3%) in the peak load for different connection lengths, but a considerable increase in the peak load (30%) when compared different connection lengths in thinner sections (Z1).

3. Zhang et. al. (2016)

[7] The lateral buckling of C- and Z-section purlins with their top flanges horizontally restrained two representative buckling theories for the lateral buckling of thin-walled beams, the traditional buckling theory and a new theory proposed by Zhang is adopted. Tong and Zhang developed a new theory for lateral buckling of thin-walled members, where the contribution of the transverse normal stress has been also taken into account besides those considered in the traditional buckling theory.

Profiles considered are four C-sections C160t20, C200t20, C250t20 and C300t20 and four Z-sections Z160t20, Z200t20, Z250t20 and Z300t20.

Table IV [7]Comparisons Between Maximum Deviations in Both Methods

METHODS	MAXIMUM DEVIATIONS
FE RESULTS	2.4%
PREDICTIONS	26.8%

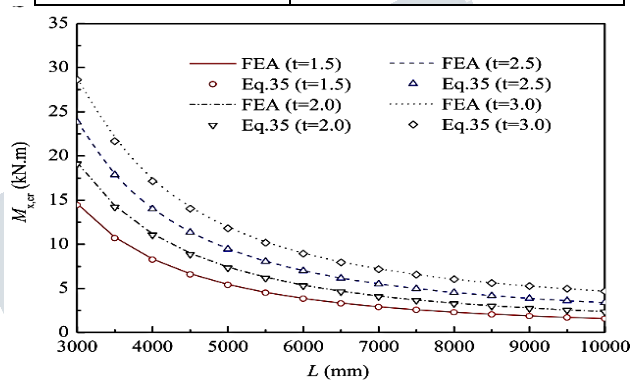

Fig. 7 [7]Graph Showing Buckling Loads of Purlins of Different Thicknesses

For purlins of an identical cross-section, the underestimation of the traditional theory is more severe for those with smaller spans. The underestimation of the traditional theory is much severe for C-section purlins than that for Z-section purlins.

Table V [7]Absolute Value of Deflection in **C and Z Purlins**

PROFILES	ABSOLUTE VALUE OF DEFLECTION
C	64.8
Z	34.0

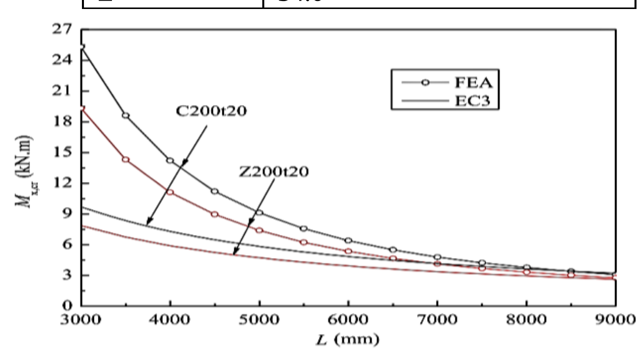

Fig. 8 [7]Graph Showing the Length vs. Moment Carrying Capacities of C and Z purlins of both Theories

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The comparisons and discussions show that the results based on Tong and Zhang's theory are in very good agreements with those form FE results using shell element modeling, while obvious differences can be seen between the results based on the traditional buckling theory and FE results.

A. Biegus (2015)

[6]Biegus did a periodic survey on the technical condition which showed that the purlins were deformed, bent and twisted and the ties were buckled. Biegus presented the results of his investigations of the load bearing capacity and rigidity of the roof deck supporting structure, aiming to determine the causes of its imminent failure condition.

A schematic of the single bay steel building is of width – about 23.57 m and length – about 57.40 m. the building has single side roof. The building's roof slope is 5%. Transverse frames with a span of 23.57 m, spaced at every 5.68 m.

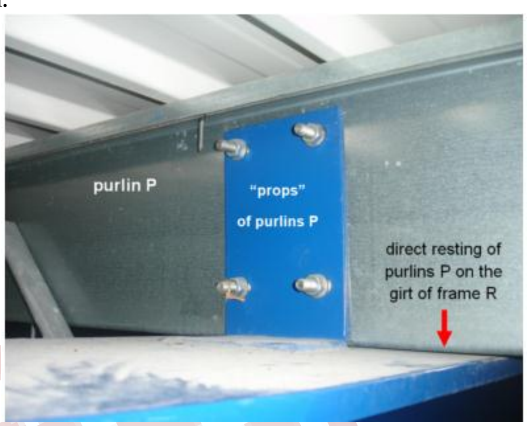

Fig. 9 [6]Purlins Resting on Roof Girt Frame

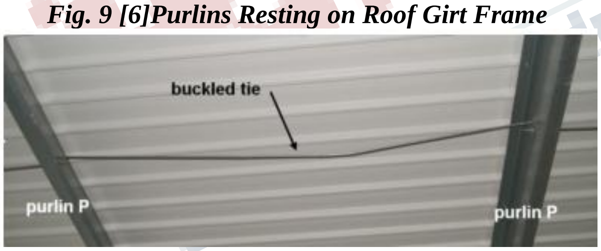

Fig. 10 [6]Example of Buckled Tie

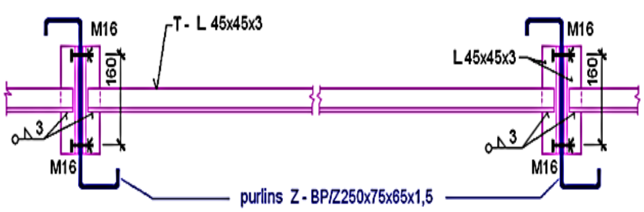

Fig. 11 [6] Proposed Design of Antitorsional Purlin Brace

Fig. 9 is the proposed system of bracing. The system consists of purlin braces T. the system limits the torsion of the cross sections of the purlins. The structural function is to reduce the horizontal displacements of purlins.

5. X Chu et.al. (2006)

[4] Xiao-ting Chu presented a numerical investigation on the local and distortional buckling behaviour of cold-formed steel zed-section beams subjected to uniformly distribute transverse loads. The analysis is performed using a semi-analytical finite strip method. The beams investigated include both detached sections and restrained sections.

Table VI [4] Various Conditions Under Which Sections Are Analyzed

CASE	STRESS DISTRIBUTION CASE DESCRIPTION
A	Two internal moments are defined. Represent a beam that is fully restrained in its lateral and rotational degrees of freedom.
B	Detached section that has no restraints and loads are applied only in xy plane.
C	Detached section but the bending is assumed to be about its major principal axis and thus the beam will deflect only along its minor principal axis direction.

Table VII [4] Profiles Considered for Analysis Under Pure Bending and Under UDL

PROFILES	DEPTH	WIDTH	LIP	THICKNESS
Z1	250	50	20	1.9
Z2	202	75	20	2.3

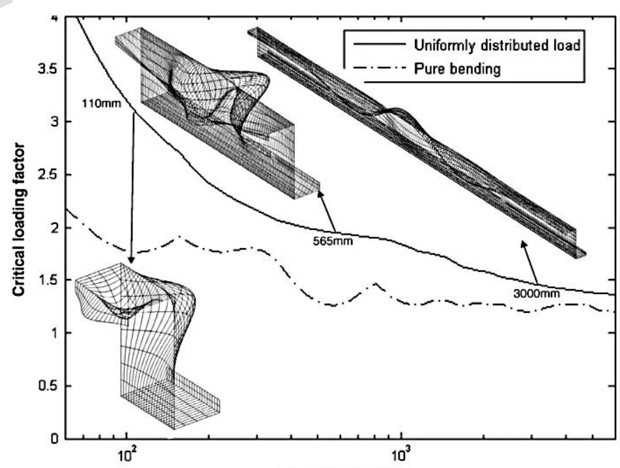

Fig. 12 [4] Critical Load Curve for Simply Supported Beam under UDL in Case a for Z1 Profile

Chu has analyzed two Z profiles for all three cases under pure bending and UDL. Hence, generating 12 various conditions for analysis.

[4]For local buckling, the critical load of a beam subjected to uniformly distributed loading is generally higher than that when the same beam is subjected to pure bending. For distortional buckling, the critical load of a beam is subjected to uniformly distributed loading is also higher than that when the same beam is subjected to pure bending.

[4]For distortional buckling, the critical load of a beam subjected to uniformly distributed loading is also higher than that when the same beam is subjected to pure bending.

[4]The zed-section beam that is restrained both laterally and rotationally can only buckle either locally or distortional, whereas a similar beam, if it is unrestrained, can only exhibit either locally or lateral- torsional buckling. However, this is based only on the particular dimensions used in the present study.

[4]For either local or distortional buckling, the beam subjected to pure bending exhibited a multi-wave buckling mode of equal wavelength, whereas a similar beam subjected to uniformly distributed loading ex-inhibited a multi-wave buckling mode but of unequal wavelengths.

6. L. Kemp, et. al. (1995)

[5]L. Kemp presented an experimental study comprising the structural behaviour of cold-formed channel, Z and zeta-profiles under gravity and wind uplift forces. Roofing area covered was of 20m2. Different inclinations were used to determine the influence of roof pitch. An inverted configuration was used to simulate wind uplift forces. The later orientation was tested with and without sag bars.

Profile	*M*	*A*	*X–X*		*Y–Y*		*J*
			I	*Z*	*I*	*Z*	
	(kg/m)	*(mm²)*	*(10³mm⁴)*	*(mm³)*	*(10³mm⁴)*	*(mm³)*	*(mm⁴)*
Channel	5·72	728	1686	26981	248	7473	2385
Z	5·72	728	1686	26981	418	8620	2385
Zeta	6·13	780	1860	28556	266	12211	2548

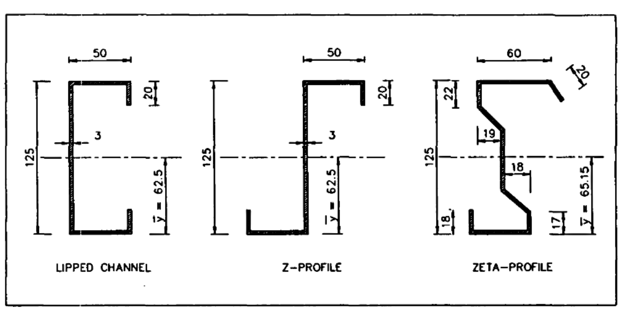

Fig. 13 [5] Properties of Profiles Considered for Analysis

Table VIII [5] Comparative Displacements at Different Inclinations for a 16.481 kN Load

PROFILE	INCLINATIONS		
	0°	10°	20°
Channel	61.6 mm	58.4 mm	53.8 mm
Z	53.2 mm	55.9 mm	51.6 mm
Zeta	52.9 mm	54.3 mm	47.6 mm

Table IX [5] Comparative Rotations (in radians) at Different Inclinations for a 16.481 kN Load

PROFILE	INCLINATIONS		
	0°	10°	20°
Channel	0.0370	0.0410	0.0229
Z	0.0230	0.0223	0.0219
Zeta	0.0220	0.0202	0.0197

Table X [5] Comparative Shear Stresses (in MPa) at Different Inclinations for a 16.481 kN Load

PROFILE	INCLINATIONS		
	0°	10°	20°
Channel	31.6	31.8	23.3
Z	27.4	26.9	17.0
Zeta	31.0	25.8	17.3

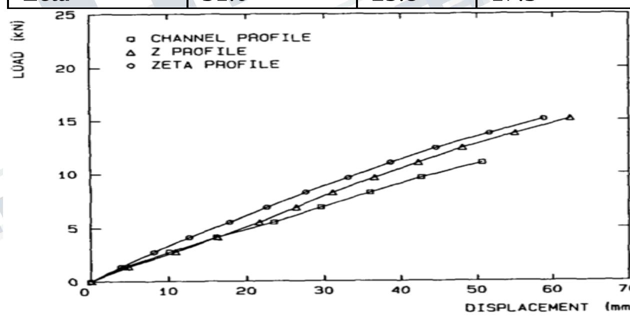

Fig. 14 [5] Load vs. Displacement, Inverted Roof with Sag Rods

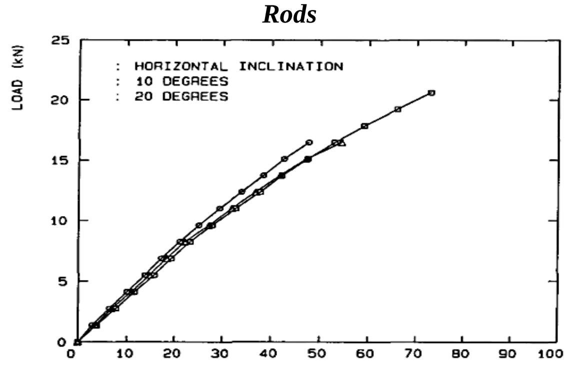

Fig. 14 [5] Load vs. Displacement, for Zeta-Profile, Various Inclinations

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III. SUMMARY OF LITERATURE REVIEW

[1]Observed that sections with lips had higher capacities in terms of moment and load. Traditional theories and ANSYS computations share similar results when applied on same case. Overlapped sections showed lower displacement when compared to experimental results[2]. Periodic study of the failure of purlins by Biegus suggests improper design being one of the major reasons for failures[6]. Within the slender limits, the ultimate flexural resistance of a lipped section may lie within 80%-100% of its full capacity [8]. FE analysis successfully predicted the load-displacement response, ultimate resistance, and modes of failure of cold-formed section with a maximum difference of 9% [8]. Simplified and codal models show similar results after analysis except for short beam. The zed-section beam that is restrained both laterally and rotationally can only buckle either locally or distortional, whereas similar beam, if it is unrestrained, can only exhibit either locally or lateral-torsional buckling [8]. Spring restraints may have significant influence on the local and distortional buckling of the purlin. The spring restraints also have the significant influence on the lateral-torsional buckling. The zeta-profile has an advantage under reversal of stresses caused by wind suction forces. Sag bars could be omitted under certain conditions, due to the greater torsional stiffness of the zeta-profile.

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