

THE JOINTS OF COLD-FORMED PURLINS

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Two problems of purlin design related to bending moment distribution in continuous and in simply supported purlin are considered. Bending moment redistribution in purlin may be realized using bearing spring (BS) elements. Preliminary results of numerical experiments show the substantial reduction of bending moments in purlin thus obtaining less section heights and web thicknesses. The approach to reduction of internal forces in purlins may help in resolving some problems typical for cold-formed thin-walled structures. There may be also some optimization possible relating BS-elements lengths and thicknesses and cross sections.

Key words: Cold-formed thin-walled profiles, Z-section, Purlin, Bending moment redistribution, Bearing spring elements

INTRODUCTION

Cold-formed, thin-walled construction used to be limited to applications where weight savings were of primary concern, such as the aircraft and automotive industries. However, following improvements in manufacturing techniques, corrosion protection, product availability, understanding of the structural response and sophistication of design codes for cold-formed sections, light-gauge construction has become increasingly widespread. Light-gauge sections used in conjunction with hot-rolled steelwork is now commonplace.

BACKGROUND

The use of thin, cold-formed material brings about a number of special design problems that are not generally encountered when using ordinary hot-rolled sections. These include [04]:

- non-uniform distribution of material properties due to cold-working
- rounded corners and the calculation of geometric properties
- Local buckling
- Distortional buckling
- Torsional and flexural torsional buckling
- shear lag
- flange curling
- web crushing, crippling and buckling.

These effects will not be outlined directly in this paper. But some aspects as being in closest relation with it and namely internal forces and moment distribution and how it depends on joint arrangements and their positioning are considered here and some simple conclusions are made and special joint arrangements offered.

There are many of researchers working on the problems of purlin connections. So, in the papers [01, 02, 07, 08, 09] experimental and theoretical investigations of connections between cold-formed steel Z sections are represented.

RESEARCH

The main features of the problem can be seen best considering simultaneously two classical problems of purlin design. One is for bending moment distribution in continuous beam and the other one relates to the simply supported beams.

Consider a 5-span Z-section uniform continuous purlin under uniformly distributed transversal load acting downwards (Figure 1). From the moment diagram one may see that moving right the first (extreme left) support reduces the moment on the second support thus equalizing it with that on any other intermediate support. Otherwise it would be reasonable to reinforce the purlin in this span and in some extent of the second span. The same applies to the extreme right simply supported end of the purlin.

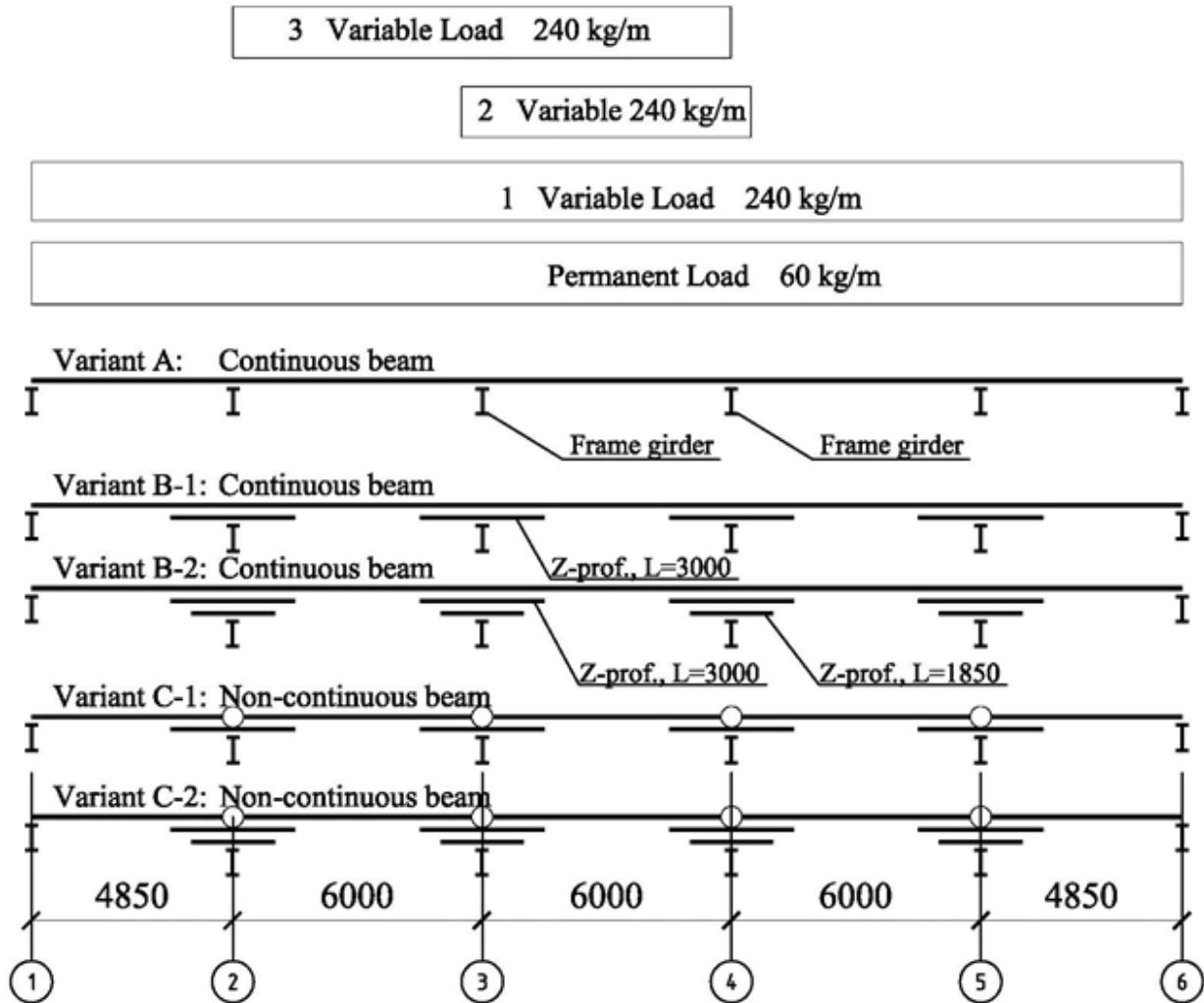


Figure 1: Five variants purlin layout under three variants of action combinations

The second almost trivial conclusion is that the most reasonable way is to arrange joints near the positions where the moment diagram intersects the beam axis. It makes about a quarter of the span from each intermediate support where the moment has the critical value.

The last note is that moment distribution is independent of the section properties distribution along the beam. And that makes it very problematic to apply any kind of bearing fasteners nearby supports.

Yet the ways there exist to redistribute the bending moment in purlin in the vicinity of a support. This may be achieved using a special support arrangement - "bearing spring support". This BS-support may comprise a number of Z-profiles stacked on one another (Figure 2). It may include just one or more supporting elements. With the friction constant around 0.1 no significant friction should be expected and calculations may be made conservatively not allowing for friction. The profiles are bolted together with the

purlin through the wider holes in the webs so that the bolts would not prevent significantly relative sliding of surfaces not to provoke local effects in the web (local buckling, shrinking, etc.). The number of profiles and the length of each should be verified based on numerical and physical experiments. The single and double BS-supports are considered in this paper.

In the example a purlin of cold formed Z-profile 142 Z 13 having three spans of 6 m is considered. The first and the last spans are 1.15 m shorter than the internal ones. The load applied includes 60 kg/m design value of roof structure weight and design snow of 240 kg/m. Three load combinations are considered: 1 – uniformly distributed 300 kg/m along the whole length of the beam being the sum of the two above, 2 - uniformly distributed 60 kg/m on the whole length and additional 240 kg/m in the third span, 3 - uniformly distributed 60 kg/m on the whole length and additional 240 kg/m in the second and third spans.

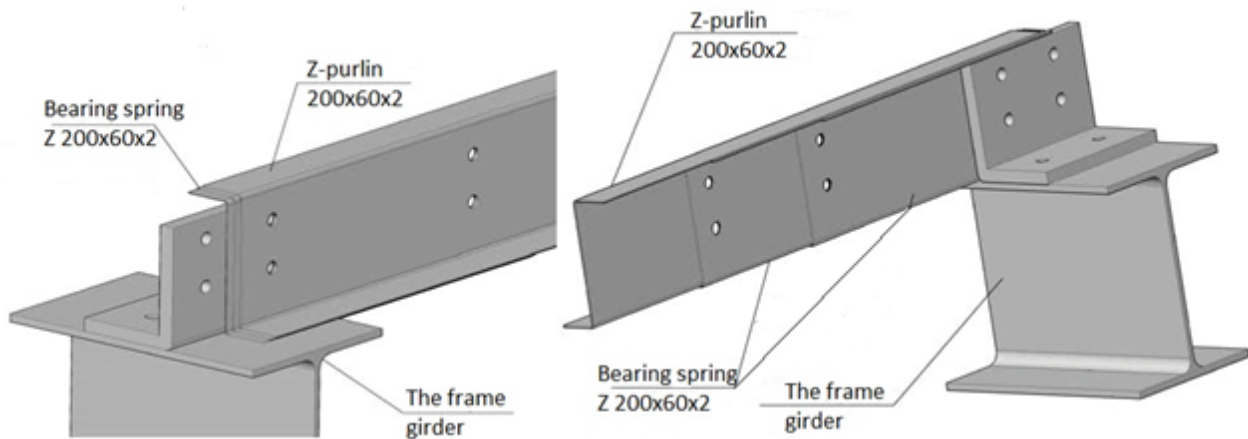


Figure 2: BS double support (the profiles are cut at the girder symmetrically)

RESULTS

The moment distributions were obtained using computer program LIRA 9.6 for all five purlin and support arrangements presented schematically in Figure 1. These diagrams (Figure 3-5) are presented for each of the three load combinations. It shows how the BS-supports take off the bending moments from the purlin beam thus reducing significantly the danger of local effects.

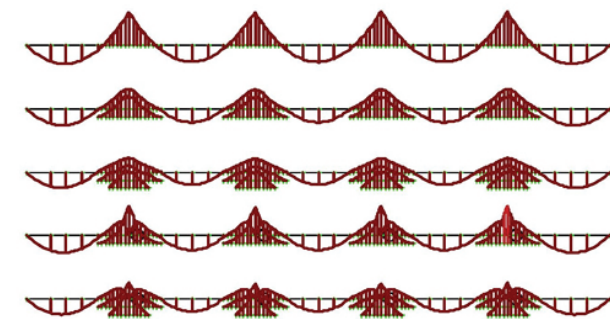


Figure 3: Moment distributions under Combination 1. From top downwards go the arrangements A, B-1, B-2, C-1 and C-2

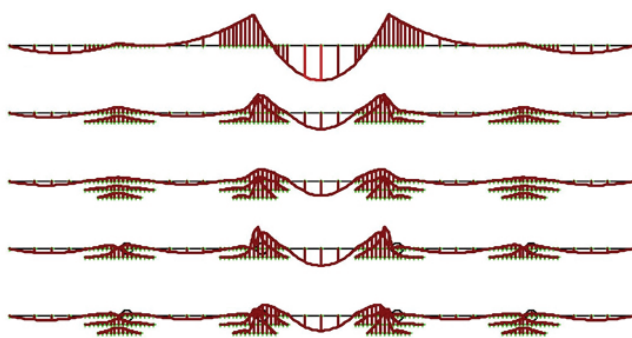


Figure 4: Moment distributions under Combination 2. From top downwards go the arrangements A, B-1, B-2, C-1 and C-2

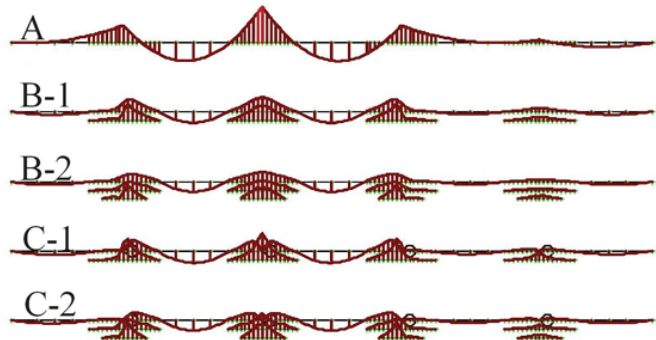


Figure 5: Moment distributions under Combination 3. From top downwards go the arrangements A, B-1, B-2, C-1 and C-2

For this last case some more detailed results are given in Figure 6-10 in graphical form. Yet even in above three pictures it can be seen that additional elements of BS-supports very effectively discharge the purlin making it possible to use the lighter steel sections. For single BS-supports there it seems to be not too much of technological problems. As for the double BS-supports (B-2 and C-2) there exist some problems that may be effectively solved by those concerned. For the lower BS-element a special nonstandard cross-section may be needed because of the flange lips (in Figure 1 no lips shown), Figure 11.

Below the moment distributions nearby the support number 3 under the load case 3 are given as an example for each of 5 support arrangements. The bending moment values are given in kNm.

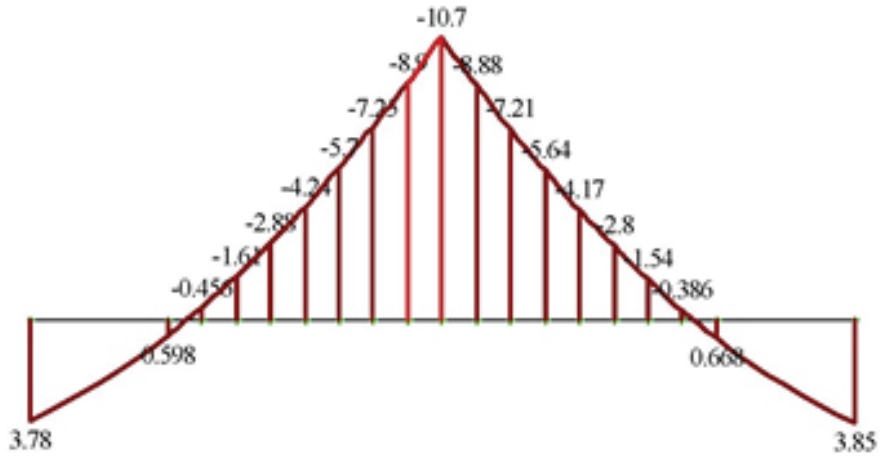


Figure 6: Moment distributions under the Combination 3. Arrangement A

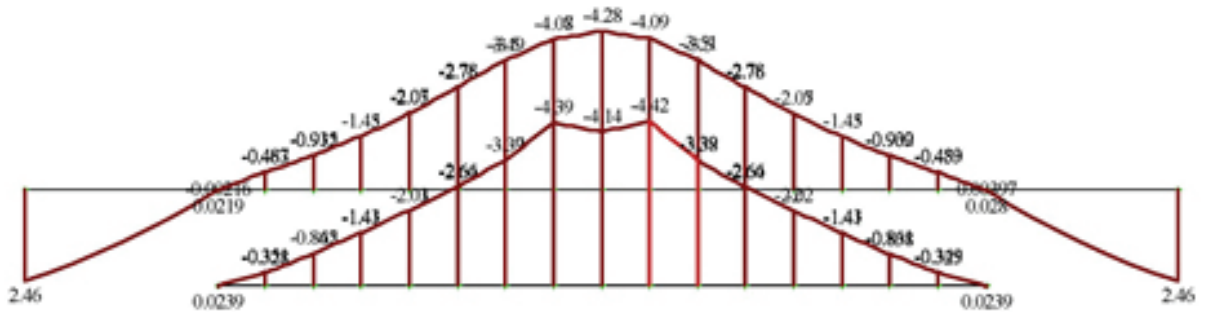


Figure 7: Moment distributions under the Combination 3. Arrangement B-1

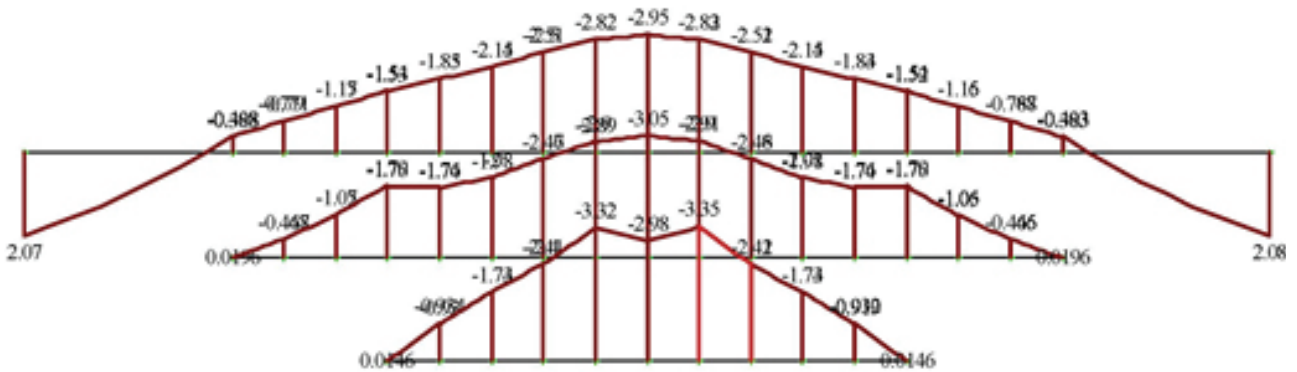


Figure 8: Moment distributions under the Combination 3. Arrangement B-2

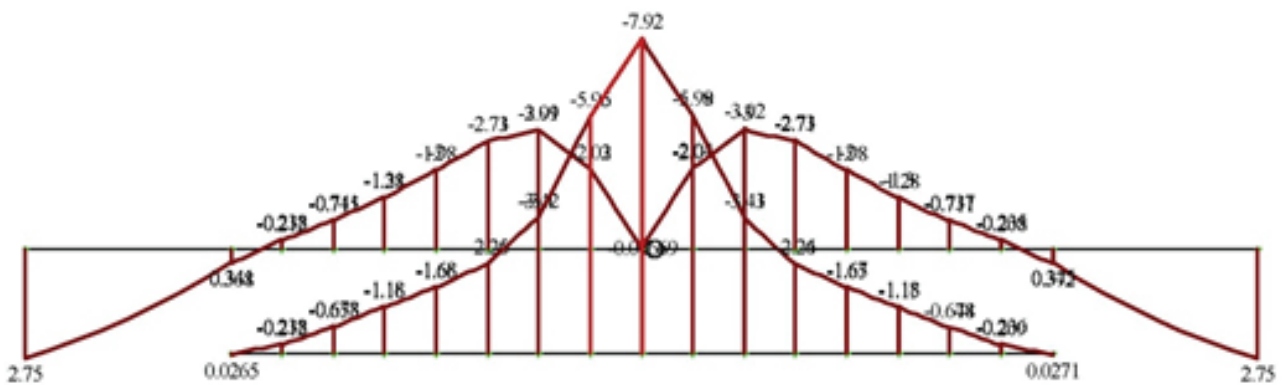


Figure 9: Moment distributions under the Combination 3. Arrangement C-1

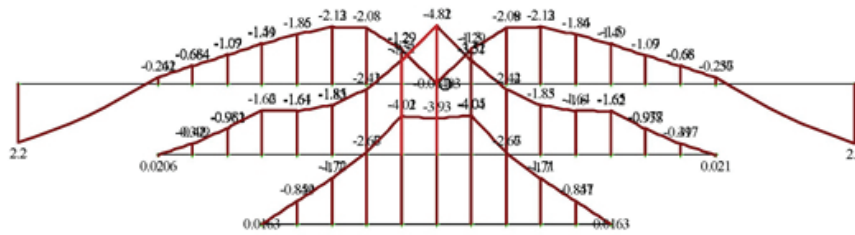


Figure 10: Moment distributions under the Combination 3. Arrangement C-2

The cases C-1 and C-2 are for non-continuous purlin having gaps on the supports.

Table 1: Maximum bending moments in different arrangements

1 Uniform Load 60 + 240 = 300 kg/m in all spans					
Variant of Support	A	B-1	B-2	C-1	C-2
Max Deflection (-)	42	30	27	35	28
M _{max} - Support (-)	887	518	372	360	255
M _{max} - Span	445	355	314	392	330
M _{max} - Upper Det (-)		370	400	882	634
M _{max} - Lower Det (-)			476		563
2 Uniform Load 60 kg/m in all spans plus 240 kg/m in the 3 rd span					
Max Deflection (-)	83	26	21	28	22
M _{max} - Support (-)	626	367	242	335	223
M _{max} - Span	700	325	290	343	237
M _{max} - Upper Det (-)		509	262	612	303
M _{max} - Lower Det (-)			427		473
3 Uniform 60 kg/m in all spans plus 240 kg/m in the 2 nd and 3 rd spans					
Max Deflection (-)	59	26	21	30	23
M _{max} - Support (-)	1066	428	295	342	253
M _{max} - Span	552	327	290	351	300
M _{max} - Upper Det (-)		442	305	792	432
M _{max} - Lower Det (-)			427		476

From Table 1 follow the maximal values for the purlin in each arrangement.

Table 1: Maximum bending moments and purlin sections for different arrangements

Parameter	A	B-1	B-2	C-1	C-2
M _{max} (purlin only)	1066	518	372	392	330
W _{req} for Steel S235 Ry = 23 kN/cm ²	46	23	16	17	14
Cross section	232 Z 20	172 Z 14	142 Z 13	142 Z 20	142 Z 13
Specific weight (purlin only), kg/m	5.87	3.41	2.84	3.05	2.84
Max moment - all elements, kN•m	1056	518	476	882	634
W _{req} for Steel S235 Ry = 23 kN/cm ²	46	23	21	38	28
Cross section	232 Z 20	172 Z 14	172 Z 13	232 Z 18	202 Z 14
Specific weight (cross section), kg/m	5.87	3.41	3.25	4.88	3.82
Weight (A – allowing for overlaps 2x0.25 m, and BS elements for the rest), kg/m	6.36	5.12	5.89	7.32	6.92

CONCLUSION

These preliminary results of numerical experiments show the way to redistribute bending moments in purlin thus obtaining less section heights and web thicknesses. The reduction of internal forces in purlin may help in solving some problems typical for overlaps. There may be also some optimization possible relating BS-elements lengths and thicknesses.

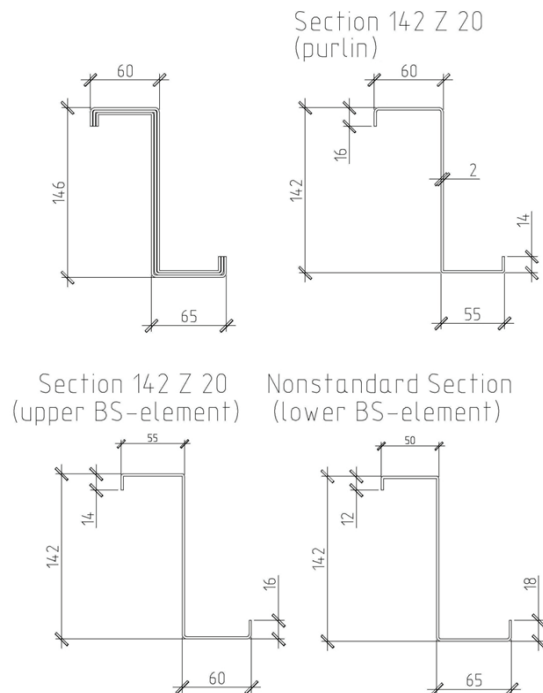


Figure 11: Example of double BS-element support arrangement with nonstandard cross section

The possible specific solutions may be valid of course only allowing for all effects concerning various modes of buckling and other possible problems typical for thin gauge plated elements using the results in a number of publications [03, 05, 06, 10, 11, 12, 13, 14].

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