Development and design analysis of a new purlin system

J. Rhodes
J. Zaras

Follow this and additional works at: http://scholarsmine.mst.edu/isccss

Recommended Citation
http://scholarsmine.mst.edu/isccss/9iccfss-session1/9iccfss-session2/3
DEVELOPMENT AND DESIGN ANALYSIS OF A NEW PURLIN SYSTEM

by

J Rhodes¹ and J Zaras²

INTRODUCTION

One of the principal uses of cold formed steel sections in Great Britain is for roof purlins. The Z purlin has been the most widely used shape for this purpose over the last two decades. This type of purlin has been the subject of extensive research in both the USA and in Europe, and various research papers have been published, for example Refs (1), (2), (3), (4)

The Z purlin has proven to be a most efficient and useful structural member over the years, and has been developed by many companies and organisations to its limit. The trend has been continually to improve the strength to weight ratio by making the cross section increasingly more slender, with the result that the most popular Z sections used in the UK at present are of dimensions which incur some degree of local buckling before failure.

There are various alternative cold formed purlin profiles in use, notably the sigma section which is a strong competitor to the Z, and offshoots of the basic Z shape have been produced in recent years with the intention of utilising the strong points of the Z profile while improving on its structural efficiency.

The objective of this paper is to outline a particular research and development programme carried out by the authors at the University of Strathclyde in conjunction with the Engineers and designers of Structural Sections Ltd., Birmingham, and their parent company Hadley Industries PLC. with the aim of producing an improved purlin of the Z type. The purlin developed is now a registered design, with patent applied for.

PURLIN DESIGN PHILOSOPHY IN THE UK

Some mention should be made at this stage of the general philosophy adopted in purlin design in the UK. Z purlins may be analysed using simple empirical rules given in the British cold formed steel code (5), or they may be designed either on the basis of testing, or a combination of testing and analysis. The design strength of a purlin is generally expressed in terms of its section modulus evaluated on the basis that the section bends about an axis perpendicular to its web.

²Lecturer. Institute of Applied Mechanics. Technical University of Lodz. Poland
This is justified to a large extent since, although the Z profile is not symmetrical, when it is connected to a metal roof by screws, as illustrated in Figure 1, the restraining effect of the connections may be considered to make such purlins bend about an axis perpendicular to the web under download, so that they may be analysed using simple beam theory, with appropriate modifications being carried out as required to take local buckling effects into account.

Thus for optimum efficiency the requirement is that for a given cross sectional area the section modulus concerning bending about the axis perpendicular to the web is a maximum. This requirement suggests that deep webs allied to thin material is a prerequisite for efficient sections. At the present time Z sections used in the UK are made with web depth/thickness ratios of up to about 130. At such depth/thickness ratios for steel local buckling of the webs is a strong possibility, and in practice, because of imperfections, the beam will suffer effects due to local buckling before the ultimate load is reached, thus reducing its efficiency. This depth/thickness ratio is therefore the limit (indeed beyond the limit) that the Z section may be taken while still retaining full efficiency.

The purlin flanges are generally limited in width to thickness ratios to produce full effectiveness, or almost full effectiveness according to the British code and the lip widths are set to ensure that they are adequate according to this code. If the empirical design rules given in the code are to be used the lip angle must not vary by more than 10° from a right angle, and even if these rules are not used the British code does not allow lips in beams to be set greater than 20° from the right angle. This contrasts with the 45° lips often used in the USA, and prevents full 'nesting' of the sections during transport. One flange is generally made slightly wider than the other to permit the use of sleeve and overlap connections.

PURLIN SYSTEMS IN COMMON USE

There are 4 main types of purlin systems in common use in the UK at the present time. These are the non continuous system, as illustrated in Figure 2(a), the double spanning system, as illustrated in Figure 2(b), the sleeved system, 2(c) and the overlap system, 2(d). In system (a) the purlins span the rafters and are supported on cleats to which they are connected by two bolts, effectively giving a support condition close to simple support. In system (b) the purlins are made to cover two spans with continuity at the central support. In system (c) the purlins are connected, generally at alternate supports, by sleeves, of similar section to the purlin, which introduce a degree of restraint on bending at the supports but not full continuity. In system (d) the purlins are overlapped at the supports to give a cross section double that of a single purlin at the points of maximum moment.

System (c) is the most popular system and by careful design of the sleeves it is possible to arrange that redistribution of moments occurs under load to produce equal maximum moments in the span and at the supports at failure, thus allowing a type of plastic design (although using elastic properties). System (d) is by far the most efficient, as in the UK the overlap lengths are made large enough to ensure that the full benefits of the double section at the support are achieved, and the system is designed as a complete unit, with end spans of different material thickness to internal spans. Despite its efficiency this system is not so popular as the sleeved system which is considered the standard system for Z purlins.

In addition to the purlin systems these sections are used as girts, or side rails which is the term used in the UK. There are various items of ancillary equipment which also must be considered in design, such as cleats, sleeves, and 'sag rods', or lateral restraints.

The system must also be designed to be used with roofs and walls made from steel or aluminium cladding, using screw connections, and with cement fibre cladding, using hookbolt connections which 'hook' the walls or roof onto the purlin lips.
DEVELOPMENT OF THE PURLIN SHAPE

Since the Z purlin has many practical advantages it was desired to retain the basic Z shape while at the same time to attain the same, or greater web depth to thickness ratios without suffering the adverse effects of local buckling. To accomplish this it was initially decided to introduce longitudinal stiffeners in the web during forming. Figure 3 shows a graph of variation of buckling coefficient, $K$, with variation in stiffener position, based on simple analysis and assuming that the stiffeners are completely adequate. This suggests that if the stiffeners are placed about one fifth of the web width from each flange the problems of local buckling in the web will be eliminated.

With this in mind a prototype section of the shape shown in Figure 4 was drawn up, having stiffeners in the webs to permit thin material to be used without incurring local buckling. Practical considerations, such as the desirability of partial 'nesting' the sections for space reasons during storage and transport, the requirement to 'overlap' purlins for some applications and the need to obtain suitable surfaces for the supporting cleats, dictated that the design be altered while still retaining the effects of the web stiffeners. After various alternative designs of practical shape had been considered the design shown in Figure 5 was adopted as that to be developed. This section has also flange stiffeners as well as additional small stiffeners as shown in the figure whose aim was not really to further stiffen the section but to introduce a greater degree of work hardening, which raises the material yield strength in these regions, taking increased advantage of the elimination of local buckling. Since the section evolved had the basic Z (pronounced zed in the UK) shape with additional enhancements which could potentially provide improved performance it was decided that this section should be named the "UltraZED".

To verify the increase in resistance to local buckling the variation in flange buckling coefficient for a slightly idealised profile of the type adopted with variation in buckle half wavelength is shown in Figure 6 for different material thicknesses for comparison with buckling coefficients for a standard Z section of the same depth and thicknesses as shown in Figure 7. The coefficients were determined using the Finite Strip approach and considering the purlin under pure bending with the tension flange restrained. For the standard Z examined the minimum flange buckling coefficient is less than the classical value of 4 generally associated with stiffened elements since the web depth is substantially larger than the flange width, and the web, even though it is under bending, is the main initiator of local buckling. The smallest wave length mode of local buckling is associated with substantial web deflections for the Z section. For the UltraZED this mode of buckling is delayed very substantially as the web influence is minimised by the web stiffeners and the flange stiffener also plays its part.

A second mode of local buckling for the standard Z, occurring at a longer wavelength, is that associated with vertical movement of the lip. With the UltraZED this becomes the main buckling mode as the effects of the stiffeners on this mode are not so significant. However, the wave length for this buckling mode to have its full effect is quite large, ie the half wave length is always greater than 0.6m, and this factor influences the possibility of this mode of buckling occurring. If the compression flange is sheeted the screw spacing of 200mm to 300mm prevents this type of buckling except at a very much lower wavelength, between connections, and a very much higher load. For unsheeted compression flanges, for example in mid span under wind uplift, the natural tendency for the flanges to rotate and decrease the lip compressive stress also delays and usually eliminates this type of buckling. At continuous support points under download the high stress gradient also affects the possibility of this type of buckling, but it has been noted that failure of double span purlins is often accompanied by this type of behaviour.

With regard to this buckling mode the UltraZED section is only about 10% better than the Z, but as has been discussed this mode is usually avoided.

For the UltraZED purlin range parametric studies indicated that for optimum benefit the purlins produced should be in general slightly deeper than comparable existing purlins and be of thinner material to produce greater load capacity for a given weight. With the advantages provided by the stiffeners the facility to use thinner material than commonly employed was available.
For the smaller purlins in the range, with web depth not greater than 200mm, the preliminary investigations suggested that material down to 1.2mm, some 20% less than the thinnest material used up to that date, could be envisaged. This raised questions regarding the behaviour of connections in thin material. To examine this aspect preliminary tests on the fixing capacity of screws in 1.2mm material were commissioned, and these indicated that screw fixing of the purlins to roof sheeting should cause no undue problems. In view of this it was decided that material of this thickness was indeed worthy of examination.

**ANALYTICAL CONSIDERATIONS**

The general plan of investigation was to use analysis in combination with testing. There were two objectives in the testing, the first being to provide suitable experimental data for use in the various analyses, for example sleeve strengths and stiffnesses, and the second being to verify the safety and accuracy of the analytical predictions.

In the analyses it was assumed that, subject to confirmation by testing, the cross section could support a maximum moment equal to the first yield moment. Thus for the non continuous system the load at failure evaluated using elastic analysis is, for the download case

\[ W_E = \frac{8 \sigma_y Z_c}{L} \]  

(1)

Thus for material with 350 N/mm² yield stress the postulated maximum load is

\[ W_E = \frac{2800 Z_c}{L} \]  

(2)

where \( W_E \) is in Newtons, \( Z_c \) is in cm² and \( L \) is in metre units.

For the sleeved system the sleeve was considered as an elasto-plastic spring having experimentally determined strength and rotational stiffness in the elastic range. For a two span system with such a spring at the centre support, as shown in Figure 8, the support moment in the elastic range is given by

\[ M_s = \frac{WL^2}{8} \times \frac{1}{1+\frac{c_1}{K_1}} \]  

(3)

The spring stiffness of the sleeve, \( K \), was required to be such that the centre support moment, \( M_s \), was greater than or equal to the maximum moment within the span. Subject to this proviso the sleeve will reach its full capacity and will then deform plastically to allow moment redistribution under further load. The maximum load attained by the purlin under these circumstances is

\[ W_E = \frac{4 \sigma_y}{L} \left\{ \frac{c}{2} + \sqrt{1 + \frac{c}{1+c}} \right\} \]  

(4)

where \( c \) is the ratio of sleeve capacity to purlin capacity, which is intended to be as close to unity as possible.

This can be written, for the steel used

\[ W_E = \frac{1400 Z_c}{L} \left\{ \frac{c}{2} + \sqrt{1 + \frac{c}{1+c}} \right\} \]  

(5)
In the case of double spanning continuous purlins it has been claimed that these can sustain similar loads to sleeved purlins. This is questionable as there is no mechanism for moment redistribution similar to that of the sleeved system, and significant plastic flow would be required to obtain the desired redistribution, which is not available in thin purlins. In view of this the capacity of this system was determined using observations from experiment.

For the overlap system theoretical evaluation of the internal and external span capacities, the overlap lengths etc., was carried out by examining a variety of purlin configurations by computer. By this means equations of the same form as those detailed were evolved to cover the worst conditions applicable to internal and external spans.

Wind uplift conditions were examined theoretically but experimental evidence was used primarily in assessing the wind uplift resistance of the systems.

**PRELIMINARY TEST SERIES**

The initial tests were carried out on specimens formed on a press brake. A number of such specimens were manufactured from 280 N/mm² yield steel and tested against commercially available Z sections of similar material yield strength and cross sectional area and weight. These tests were somewhat speculative as manufacture of the sections by press brake was difficult and accuracy of dimensions and angles could not be readily maintained. The tests did strongly suggest, however, that the postulated advantages of the new section could be realised, as the press braked specimens generally withstood higher loads before failure than the Z sections used for comparison. It was then decided that, in the light of the promise shown by these tests, a rolling mill should be set up and subsequent testing carried out on commercial quality specimens.

**MAIN TEST PROGRAMME**

The testing and development process lasted for about two years, and during this time various changes were made to the cross section, the end supporting methods and the material. The range of section depths considered was from 145 mm to 285 mm, and for the smaller depths modified designs were adopted, in which the additional small stiffeners were eliminated. The main change to the original plan was the adoption of higher yield material. It was found that since local buckling was largely eliminated an increase in material yield strength would for many cases produce a proportional increase in member strength, and thus increasing the yield strength from 280 to 350 N/mm² was very profitable in terms of increased load capacity.

Two general types of testing were carried out, component testing and testing of full assemblies. The component testing was undertaken to obtain information on section performance and the behaviour of connections, sleeves, overlaps etc. in the development of the purlin and its ancillary equipment without having to resort to large scale testing in all instances. The testing of full assemblies was carried out in a vacuum box test rig to check the performance of the complete systems developed. Both types of testing were carried out in parallel.

**COMPONENT TESTS**

A typical component test set up is shown diagramatically in Figure 9. Here short lengths of purlin are aligned and fixed together with sheeting. The ends of the purlins are supported on cleats using a slotted lower bolt hole, with the bolts being only finger tight to produce simple support conditions. Loading is applied through cleats at the centre point. This gives experimental evaluation of the section moment capacity. To ascertain sleeve capacity and stiffness the continuous purlin is replaced by lengths of purlin with a sleeve connection at the centre as shown.
in Figure 9(b). Similar arrangements can be made for overlap connections etc. The sleeve stiffness can be evaluated on the basis of comparison of the results of continuous and sleeve tests.

Figure 10 shows results of tests on the deepest purlin of 1.2 mm material, of web depth 200mm. Here the continuous purlin test shows that the section withstood a little more than its theoretical elastic maximum load, determined on the basis of simple beam theory and using the gross cross section. The sleeve test did not take the theoretical maximum load, failing about 10% less than this value. The sleeves used in this instance were those finally adopted for commercial use. It was found in general that in the thinnest material the sleeves tended to distort quite substantially as failure approached and the lips of sleeve and purlin disengaged at failure, thus inducing the failure earlier than would otherwise have been the case.

This effect was only noticed in the thinnest material, and was most evident for the smallest depth purlins, probably because for these purlins the connection bolts are close to the web centre line. Figure 11 shows the case of the smallest depth purlin in the thinnest material. In this case the full section failure moment obtained from the figure is about 18% higher than the theoretical elastic maximum moment, and indeed higher than the theoretical fully plastic moment. Curve 'A' shows that the sleeve attached as normal failed at about 75% of the theoretical elastic failure moment. To examine the situation further in this case, curve 'B' shows the behaviour obtained when sleeve and purlin were connected near the sleeve ends by a single screw through the flanges, which prevented disengagement of the lips. Here the sleeve capacity becomes again greater than the theoretical elastic capacity. Various methods of providing this extra capacity in a way which would be foolproof on site were considered, but it was eventually decided simply to use a reduced sleeve capacity in determining the safe loads for the sleeved system. The reduced capacity was taken as that obtained from the poorest of all the sleeve test results on the final product.

Results of component tests on the deepest purlin in the range, with the thinnest material used for this depth, are shown in Figure 12. Here again the full section moment capacity is greater than the theoretical fully plastic capacity, and the sleeve capacity is greater than the theoretical elastic capacity. It is of note that in this particular case the material tested had a yield strength of only 320 N/mm² instead of 350 N/mm² as used in determining the theoretical capacity.

TESTS ON ASSEMBLIES

The full scale tests were carried out in a vacuum box, as illustrated in Figure 13, of length 12.19m (40 ft), width 2.44m (8 ft) and depth 1.22m (4 ft). The purlins were set up in opposing pairs, usually over two spans and the roof sheeting fixed as in the practical situation. Polythene sheeting was then spread over the complete system and taped to the sides and ends of the vacuum box to provide an airtight chamber within the box. Air was sucked out from the box using the laboratory vacuum system to produce the desired loading. Deflections and vacuum were measured electronically as loading progressed, and mechanical measurement systems were used as a backup.

In testing to simulate download conditions, such as snow load, the set up was as shown in Figure 13(a). In testing under simulated uplift conditions, i.e. wind suction, the sheeting was fixed to the bottom flanges of the purlins as in Figure 13(b) with the vacuum tending to suck the sheeting from the purlins, as in the practical situation.

Single span purlins of any length up to 12.19m and double span purlins of up to 6.09m per span could be tested directly in the vacuum box. Since the effects of continuity, or partial continuity, are very important for some systems, spans of greater than 6.09m had to be examined in a two or more span situation. To accomplish this the required restraint conditions were simulated for longer spans using overhangs fixed to additional supports as illustrated in Figure 13(c).
Typical load-centre deflection curves obtained from these tests are shown in Figures 14 to 17. In Figure 14 the behaviour of a sleeved purlin of depth 145mm and thickness 1.2mm, ie the smallest and thinnest of the range, is illustrated, under download and simulated wind uplift conditions with span of 6.06m. Under download the failure load was about 8% less than the maximum elastic load calculated on the basis of complete redistribution of the moments to equalise span and support moments. This was accompanied by the disengagement of the sleeve and purlin lips noted in the component tests for the same purlin and shows good agreement with the observations obtained in the component tests. Under uplift conditions the central part of the purlins have their compression flange unsupported, and this has the effect of promoting lateral deflections which reduce the purlin stiffness and introduce increased stresses leading to earlier failure than under download conditions. This is confirmed by the curves, but it is seen that for a span of 6.06m, even without any lateral restraints within the spans, the reduction in load is not substantial, and with the reduced load factor which the UK standard allows for wind loading the purlin can be designed to carry the same uplift load as download.

The figure also shows that the purlin deflections are, as would be expected, in the range between simple support and continuous beam deflections. These indeed are in very good agreement with values calculated on the basis of the sleeve stiffnesses determined from the component tests. Both component and purlin tests shown for this section used the final sleeve dimensions adopted for commercial use. These dimensions were arrived at by initially calculating a minimum sleeve length to achieve theoretically the required connection strength and then systematically increasing this length to improve the connection stiffnesses obtained from the component tests.

Figure 15 shows the behaviour of the same purlin under download and uplift loadings as an internal span of an overlap system. As mentioned previously, this system is very strong because of the doubled section at the supports, and the stiffness is significantly greater than that of the sleeved system. Again the uplift loading shows reduced strength and stiffness in comparison with the download case, but not substantially so.

Figure 16 shows the behaviour of a sleeved purlin 285mm deep and 1.8mm thick under download over a span of 9.06m. As in the corresponding component test, Figure 12, the load capacity is greater than that theoretically determined on the basis of analysis using the gross cross section. For all thicknesses other than the smallest this type of behaviour was noticed, and capacities greater than the theoretical fully plastic capacity were obtained in some cases. It would seem that the increases in yield strength due to the somewhat intensive cold forming do increase the section moment capacity.

In the case of uplift loading over the same span, Figure 17 shows curves for three different lateral restraint conditions for this purlin, ie no restraint, one restraint at mid span, and two restraints positioned at 0.375 times the span from each support. As in this case the yield stresses for each purlin were found, after the tests, to differ the curves have been non-dimensionalised to provide a straightforward basis of comparison. The addition of lateral restraints is seen to increase the strength of the member, but only by a small amount. This is so because the elastic restraint provided by the sheeting makes lateral buckling behaviour somewhat length independent if the length between restraints is greater than a certain value. There have been several different theoretical approaches postulated to deal with the behaviour of purlins under wind uplift eg. (4), (6), and an analytical procedure was also developed in this investigation. However, such approaches rely on accurate assessment of the purlin-sheeting interaction. In the case of purlins manufactured for use on unspecified sheeting then this raises difficulties, and rigorous theoretical analysis requires information which cannot be obtained in the general case.

For most of the tests carried out a rather light trapezoidal sheeting, of 0.5mm material thickness, was used. The only exceptions to this were for some particular tests, when using hook bolt fixings, in which a very light sinusoidal steel sheeting was used, which gave very little restraint to the purlins.
DESIGN EXPRESSIONS

On the basis of analysis in conjunction with experimentally derived parameters for various aspects of the systems, such as stiffness and capacity of sleeves, stiffness of overlaps etc., a series of equations were obtained covering the behaviour of each system.

For the non continuous system the purlins were found to be capable of taking the full elastic load as given by equation 2. Applying a load factor of 1.6 to this gives the design load as

\[ W_D = \frac{1750Z_c}{L} \]  

(6)

In the case of the sleeved system, the sleeve design was such that except for very short spans the sleeve could achieve its full capacity, and, except for very thin material, this was at least equal to the theoretical elastic capacity of the purlin. Using this, with a \( c \) factor of 1 in Equation (5) together with a load factor of 1.6, results in a design load expression of \( W_D = 2550Z_c/L \). However in view of the tendency for the sleeves to disengage in the thinnest material the factor 2550 was downgraded, on the basis of the worst single test result, to 2330. Thus on this basis the design load is, for most cases

\[ W_D = \frac{2330Z_c}{L} \]  

(7)

Only limited testing of the double spanning system was carried out, on the thinnest material, and this suggested a smaller design load than for the sleeved system, of magnitude

\[ W_D = \frac{2150Z_c}{L} \]  

(8)

For the overlap system the end spans, with a single overlap connection, and internal spans, with both ends overlapped are covered by the formulae

End span:-

\[ W_D = \frac{2840Z_c}{L} \]  

(9)

Internal span:-

\[ W_D = \frac{4127Z_c}{L} \]  

(10)

These expressions for the various systems are of course only applicable if the purlins are fixed according to the manufacturer’s instructions. There are also various other design conditions, such as shear, deflection etc. which are not detailed here.

For side rails the combination of wind loading and gravity and sheeting loads is taken into account using linear interaction equations.

In the case of wind uplift loading multiplication factors covering a variety of different conditions of sheeting and restraint were obtained for design use.
SUMMARY

An outline of the steps taken in the development and examination of a new purlin system has been presented. Typical component tests, and corresponding assembly tests involving the same purlin, have been shown and some of the final design expressions have been specified.

The new purlin is now on the market in the UK, and is proving popular.

APPENDIX 1. REFERENCES


APPENDIX 2. NOTATION.

E = Modulus of Elasticity
I = Second Moment of Area
K = Buckling coefficient, or Spring stiffness of a sleeve
L = Purlin span in metres
Wd = Design load for purlin in Newtons
We = Elastic capacity of a purlin in Newtons
Zc = Elastic modulus (compression) in cm²
b = Width of an element
c = Ratio of sleeve capacity to purlin capacity
t = Material thickness
σr = Buckling stress
σy = Yield stress
FIG. 1

FIG. 2 PURLIN SYSTEMS

FIG. 3 VARIATION IN BUCKLING COEFFICIENT WITH STIFFNER POSITION
FIG. 4 INITIAL PROTOTYPE

FIG. 5 ULTRAIZED SECTION

\[ \sigma_{CR} = \frac{\pi^2 E}{12(1-V^2)} \left( \frac{t^2}{L^2} \right) \]

Web: 200 mm
Flange: 72 mm
Lip: 20 mm

FIG. 6 K FACTORS FOR ULTRAIZED

FIG. 7 K FACTORS FOR Z

FIG. 8 THEORETICAL MODEL OF SLEEVE BEHAVIOR
FIG. 9  Typical component test set up

FIG. 10  Component tests on 200 mm deep section

FIG. 11  Component tests on 145 mm deep section

FIG. 12  Component tests on 285 mm deep section
Sealing tape, Purlin, Sleeve, Sheeting, Vacuum box, Sealing foil, Cleat, Cross beam, Longitudinal beam, Air outlet

(b) Uplift loading

Sealing tape, Purlin, Sleeve, Sheeting, Vacuum box, Sealing foil, Cleat, Cross beam, Longitudinal beam

(a) Download

Test span

Set up to simulate fixity at end of test span.

(c) Set up for long spans

FIG. 13 DIAGRAMATIC ARRANGEMENT OF VACCUM TEST RIG.
(Not to scale.)

Vacuum Pressure

<table>
<thead>
<tr>
<th>cm H₂O</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>12</th>
<th>14</th>
</tr>
</thead>
</table>

6:06 m 6:06 m

145 mm

Sleeve

Full continuity

Download

Simulated wind uplift

Notes: 1 cm H₂O = 0.725 kN per p
additional loading due to p... and sheeting weight = 0.69 kN per purlin

Simple support

FIG. 14 VACCUM TESTER ON 145 mm DEEP SECTION
**FIG. 15 TESTS ON OVERLAPPED PURLIN 145 mm DEPTH**

**FIG. 16 DOWNLOAD BEHAVIOUR OF 285 mm DEEP PURLIN**

**FIG. 17 WIND UPLIFT LOADING ON 285 mm DEEP PURLIN**