Analysis of Steel Profile Sheets

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***Abstract*–In recent years extensive research is being conducted on the CFS members of various configurations. Thin sheet steel products are extensively used in building industry, and range from purlins to roof sheeting and floor decking. These Cold-formed steel sheets are widely used as the secondary structural members in buildings to support roof sheeting, side cladding or composite slabs for floors.**

These slabs are generally studied in their composite action with concrete infill and hence quantities studied are about the interface shear, provision of keys for bonding etc. Focus on the behavior of the sheets in their plain state is not given. This is of equal importance given that knowledge of the behavior of plain sheets will enhance the understanding in composite form as well as that at the ultimate limit state, the strength of the sheets will be the last reserve. In cold formed steel members for serviceability and deformation consideration, it is essential to consider the interaction and deformation of the thin elements of the sheet.

Studies on profile sheets have focused extensively on composite systems and panels with filler materials while behavior of sections made from thin sheets are limited to cold formed steel structural members. A study on plain sheets to find the performance of its individual behavior is done using ABAQUS – plain steel sheets find application particularly in the usage of sheet piles and other load bearing applications where the sheets are used in plain form.

Keyword: Finite element analysis; decking sheet; local bending; Cold formed steel

I. INTRODUCTION

Decking profile steel sheets are widely used for composite floor system and roofing system. The cladding materials is made up of various materials such as zinc coated, titanium coated steel etc. These sheets are used as the floor of high buildings by saving both the steel quantity and extra save cost both in material, labor and maintenance. The factors influencing the strength of deck sheets include slenderness ratio (height to width ratio), length of corrugations, thickness of sheet and stiffeners. Metallic coatings require a very high standard of product and installation, whereas plastisol-coated cladding requires good workmanship, but is more tolerant to small inconsistencies.

Steel profile sheets are manufactured in various forms. When used as decking for composite slabs they are sometimes specified by the supplier regarding the span range in which they are to be used. These slabs are generally studied in their composite action with concrete infill and hence quantities studied are about the interface shear, provision of keys for bonding etc. Focus on the behavior of the sheets in their plain state is not given. This is of equal importance given that knowledge of the behavior of plain sheets will enhance the understanding in composite form and also the fact that at the ultimate limit state, the strength of the sheets will be the last reserve. Therefore, in this study, plain sheets are numerically studied to diagnose their behavior under gravity loading (as in slab flooring case). It is necessary to observe the different elements of the sheet such as the slant, crests and intermediate to get a true picture of the interaction between these elements and the overall strength of the sheet as well.

II. FINITE ELEMENT MODELLING

A. Element type, mesh size and material model

The finite element programme of ABAQUS version 6.13 was used to develop a finite element model, which aimed to simulate the behavior and strength of cold-formed steel beams tested by other researchers.

The profile sheets are models using the shell element S4R5 available in ABAQUS. The material model used in the verification is identical to that available from sheet suppliers. 3D space, Deformable body, Shell feature, planar type was used in this study. Isotropic Elastic, perfect plastic material model was used for the part creation in the parametric study. The Young's modulus and Poisson's ratio of the material were taken as 2×105 N/mm2 and 0.3 respectively, with shell thickness 2mm & approximate global mesh size as 25 for parametric finite element model.

B. Boundary conditions and loading applications

Six profile sheets with different combinations of crest height (44, 51, 75, and 80) with and without stiffeners, were analyzed with suitable Displacement/Rotation simply supported type edge boundaries. The boundary conditions were applied as two different cases parallel to corrugation and transverse to corrugation. The external load applied was a uniform pressure load in the gravity direction. Coarse aggregate.

Table 1: Properties of profile sheets studied

Model	Profile Depth	Crest Width	Stiffeners	Uniform Pressure	Bc
1	44	35	NO	1N	Parallel to corrugation
2	75	130	YES	0.3N	Parallel to corrugation
3	75	130	NO	0.004N	Parallel to corrugation
4	51	140	NO	1N	Transverse to corrugation
5	51	140	YES	0.5N	Transverse to corrugation
6	80	140	YES	1N	Transverse to corrugation

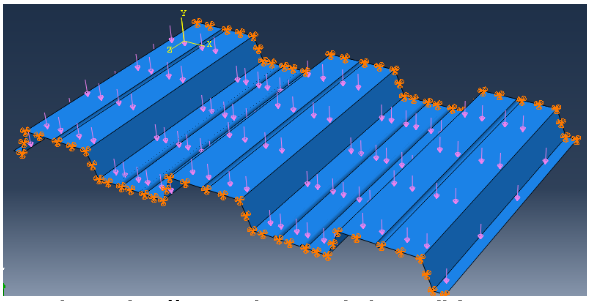

Fig 1. sheet with stiffeners and supported edge parallel to corrugation

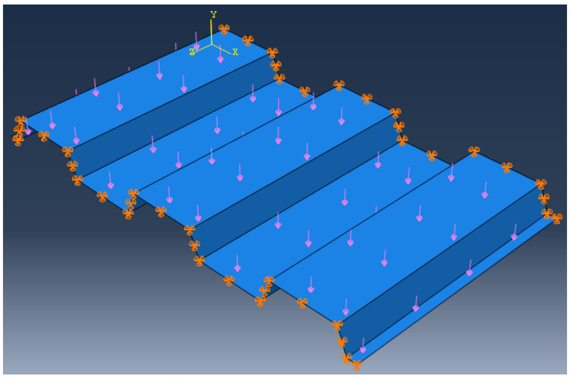

Fig 2. sheet without stiffeners and supported edge parallel to corrugation

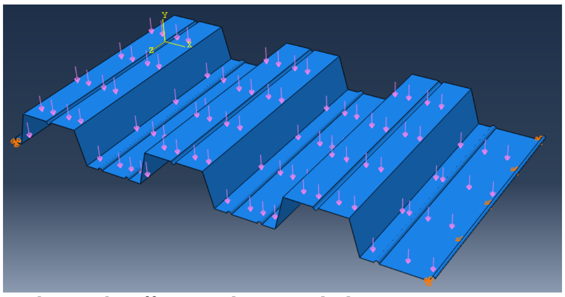

Fig 3. sheet with stiffeners and supported edge transverse to corrugation

C. Model Analysis

Under the applied pressure load, the analysis predicts the bending deformation of the profile sheets. Stiffeners are provided to enhance the buckling capacity. Static-Riks analysis step type are best suited to unstable buckling/collapse as it uses arc method to find response of the loaded structure where there is change in stiffness. A displacement along the x-direction of crest and inclined portion is observed. In a single case partition has been made midway between 2 points (near stiffeners & near corners) since a regular and uniform mesh was not obtained..

D. Material stress strain relationship

A steel stress–strain relationship is assumed to be of elastic–plastic nature with a nominal plateau slope in accordance. Stress–strain relationship is determined separately for each crest, trough and slant portion on the surface of the profile sheet. The plastic strain is 0 with plastic yield stress 250 MPa.

III. RESULTS AN DISCUSSIONS

E. Numerical analysis results

Six models were prepared for computation with different parameters and their bending behavior is studied. Under the applied pressure load, the analysis predicts the bending deformation of the profile sheets.

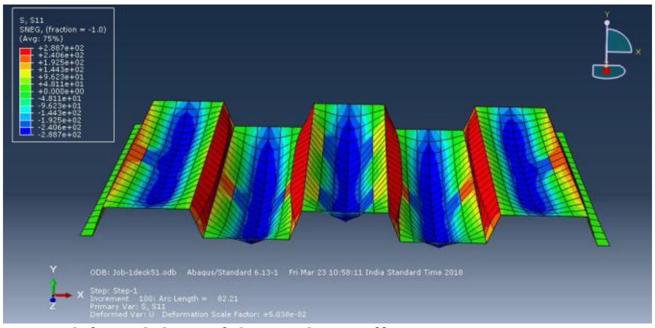

Fig 3. deformed shape of sheet without stiffeners transverse to corrugation

The profile sheet without stiffeners with boundary conditions transverse to corrugation has the similar bending deformation as in Fig 3. The slant portion gets deformed first and simultaneously deforms the crest and trough. Crest bents between two edges and in the inclined portion there occurs a tension zone. The deformation of the slender inclined portion decreases the rigidity of edges of crest and the trough. The trough portions are critical to design and lead to buckle.

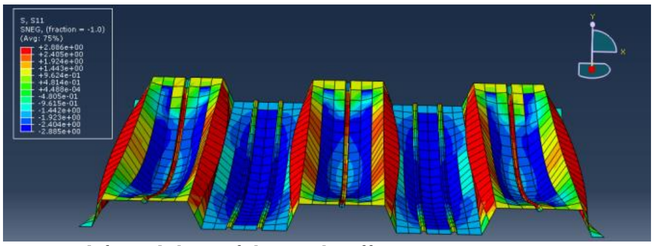

Fig 4. deformed shape of sheet with stiffeners transverse to corrugation

Since trough portions are critical to design they lead to buckling, to enhance the buckling capacity stiffeners are provided. Fig 4 shows the deformation of profile sheet when stiffeners are provided. The deformation of the slender inclined portion decreases the rigidity of edges of crest and the trough.

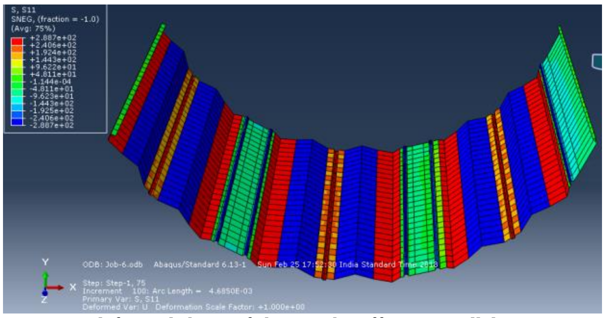

Fig 5. deformed shape of sheet with stiffeners parallel to corrugation

Fig 5 shows the deformed shape of the profile sheet with boundary conditions parallel to corrugation when stiffeners are provided. The sheet bents along x-direction of crest and slant portion where there occurs a curling/opening up. In the crest portion near the stiffeners there occurs a tension and in the trough portion there occurs compression, this may be due to occurrence of curling.

F. Comparison of results from stress strain curve

Stress–strain variation is extracted separately for each crest, trough and slant portion on the surface of the profile sheet. Maximum principal stress and strain curve were plotted in the model 1 without stiffeners. Maximum principal stress in the y axis and maximum principal strain in the x axis is plotted for the model 1 without stiffeners for load 1N and BC paralllel to the corrugation.

S11 is the direct stress obtained from model 2. Since they undergo majorly bending under the gravity loads. The element 1671 from the stress strain above shows that the slant portions are low stressed, due to its inclination with the applied loads.

Model 3 without stiffeners with load 0.004 and BC parallel to the corrugation is shown above. The element 509 from the stress strain above shows that the slant portions are low stressed, due to its inclination with the applied loads.

A steel stress–strain relationship is assumed to be of elastic–plastic nature with a nominal plateau slope in accordance. In Model 1 element 226 (slant portion) are low stressed, since element 3655 has already reached failure and further stress redistribution needs to occur in element 226. Pressure from loads act in Y (gravity) direction. Under vertical loading the trough portion gets yielded and are critical for design since they undergo majorly bending under the gravity loads hence, stiffeners are provided to enhance the buckling capacity of the sheet.

G. Failure von mises vs load factor

It uses Von Mises stress, the measure of equivalent stress. Load Proportioning Factor is used to multiply the load in the load module. Von Mises vs load factor curve is graphed for the crest, trough and slant portion of the profile sheet. This can be used as an indicator to judge at what load factor, the sheet can be said to have attained its ultimate load.
In model 1 element 1671 (crest portion) using the von Mises stress, LPF at which sheet failure starts can be seen. The stress increases initially and seems to get unloaded around the LPF at which crest starts to yield. Ultimate load is obtained from the LPF at which crest starts to von Mises stress reaches yield value.
Under vertical loading the trough portion gets yielded and are critical for design since they undergo majorly bending under the gravity loads.

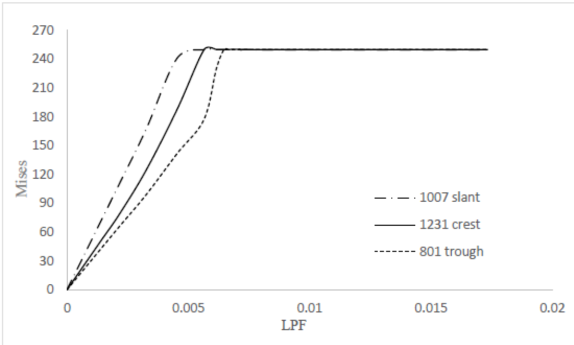

Fig 6. Von Mises equivalent stress vs LPF for Model

Slant portion is more resistant to the action of gravity loads compared to other crest and trough portion.

Using the von Mises stress, in the crest portion LPF at which sheet failure starts can be seen. The stress increases initially and seems to get unloaded around the LPF at which crest starts to yield. Ultimate load is obtained from the LPF at which crest starts to von Mises stress reaches yield value.

H. Load factor vs displacement

Load Proportioning Factor is used to multiply the load in the load module. A displacement along the x-direction is observed. Displacements along Y indicate that slant portion in the middle exhibits greatest stiffness. The deformation of profile sheets is studied by its bending behavior.
Load factor vs displacement for u1, u2, u3 is compared. There is observed a displacement along the x-direction for the crest and slant portions of the sheet, and this also points to the occurrence of curling. In case of unstiffened model the displacement graph is flat after its yield point, hence there is no stiffness reserve. Slant portion is more resistant to the action of gravity loads compared to other portion.
This load factor is multiplied with the actual load. The divided load values of stiffened and unstiffened sheet gives the ratio. When depth increases the slant height increases

which in turn decreases the slant slenderness resulting in larger deformation which consequently deforms the crest and the trough portion. The effect of stiffeners has 1.2-2.0 times the load value when compared to unstiffened sheets. For lower depth the difference between the load values of stiffened and unstiffened sheet is less when compared to sheets having higher depths.

IV. INFERENCE

Under vertical loading the trough portion gets yielded and are critical for design since they undergo majorly bending under the gravity loads. There is displacement along the x-direction of the sheet, and this points to the occurrence of curling. The deflections obtained are extremely high since no infill is used. But since study is confined to plain sheets, focus is on pattern than values. The effect of stiffeners has 1.2-2.0 times the load value when compared to unstiffened sheets. When depth increases the slant height increases which in turn decreases the slant slenderness resulting in larger deformation. The deformation of the slender inclined portion decreases the rigidity of edges of crest and the trough.

V. CONCLUSION

FE Analysis of 6 different profile sheet combination using general purpose FE package ABAQUS was carried out to find the bending behavior of profile sheets with and without stiffeners by varying the profile depth, different loading and boundary conditions. Various combinations of profile depth, crest width and effect of stiffeners were applied to the sheets and analyzed with suitable Displacement/Rotation simply supported type by varying the pressure load and supported edge parallel to corrugation and transverse to corrugation. The behavior of the sheets are ascertained at different location namely crest, trough and slant through their stress plots as well as their load factor vs deflection plots.

For lower depth the difference between the load values of stiffened and unstiffened sheet is less when compared to sheets having higher depths. The effect of increase in load ratio is more for greater depth. When there is greater depth the slant load decreases resulting in deformation, hence there should be some limitations for depths, or the slant may also require stiffeners. The study highlights that provision of stiffeners for the crests alone may not be sufficient in achieving greater strength, and the slants should be capable of providing sufficient rigidity to make the stiffened crests effective.

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