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ANALYSIS OF CORRUGATED METAL SHEET ROOFING ON IMPACT LOADS AND ENERGY LEVELS FOR BUILIDING CONSTRUCTIONS

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Abstract: Construction is the process of constructing a building or infrastructure. Construction as a industry comprises of 6 to 9 % of GDP in India. The use of corrugated metal sheet roofing is on large scale in rural as well as urban regions of India. Most of the market consumed by the corrugated metal sheet roofing is residential building constructions. As concerned with the safety and the reliability of the corrugated metal against all the impact loads and energy level, the material needs to be tested under certain energy levels. So as to attain the safety parameters against all set of conditions. It is high time to analyse the corrugated metal sheet roofing on impact load and energy levels for building material, for sustainable and material selection.
Index Terms: Impact, GI Sheet, corrugated metal sheet.

I. INTRODUCTION

The corrugated metal sheet roofing are either galvanized iron or aluminum, whereby GI sheet is susceptible to rapid corrosion of zinc; which is coated on to the corrugated metal sheet roofing respectively. The corrugation make the thin sheets stiff enough to span between two purlins without sagging. Thus large area can be roofed with a minimum of supporting construction making the roof light and cheaper with minimum use of timber or steel framework. Thin gauge sheets are often too weak to walk on and can be dented, punctured or turn off by strong winds. Major problem of sheet metal roofing are as follows:

- Immense heat transmission to the interior, during the sunshine and water condensation on the underside when roof cools down at night;
- Unbearable noise caused by heavy rains;
- Havoc caused by whirling sheets that are ripped of in tropical windstorms;
- Poor fire resistance.

Many of these problems can be alleviated with the good design material qualities and workmanship. Such roofing should tee avoided areas of intense solar radiation and rapid temperature changes to avoid hot indoor climate and condensation problems. In most cases it is advisable to construct a suspended ceiling providing a ventilated air space which removes the accumulated heat before it can reach the interior.

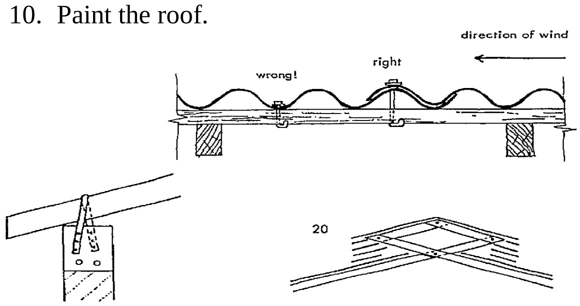
The air space also reduces the noise problem during rains. In addition shorter distance between purling as well as felt or rubber washer at the suspension points, rigid bolt connections and thicker gauged sheets help to reduce sound transmission. Similarly thicker sheets, rigidly fixed hook bolts with large metal washers, to avoid bimetallic and avoid overhangs are the measure to prevent damage by strong winds. Overlap of roofing sheets must take into consideration the main direction of wind; rafters should be firmly held by fastening strap or reinforcing bar, which is embedded in concrete or masonry.

The special features of corrugated metal sheet roofing are as follows:

1. The special property of corrugated metal sheet roofing are, they are light roofs and can be assembled quickly.
2. The metal sheet ranges into medium range as the economic aspect is concerned.
3. It provides low to medium stability.
4. Average construction skills are required for metal sheet roofing.
5. The carpentry tool is equipment material required for metal sheet roofing.
6. It provides very good resistance to earthquake.
7. It provides good resistance to rain, but creates extremely loud noise.
8. It provides good climatic stability.
9. It is widely used in all the countries for building construction purpose.

The steps involved in the installation of the corrugated metal sheet roofing are as follows:

1. Measure your roof.
2. Buy the metal plates.
3. Lay the roofing felt.
4. Lay and secure the first metal panel.
5. Complete the first row.
6. Finish the first side of the roof.
7. Lay and secure the metal panels on the other side.
8. Attach the peaked ridge cap.
9. Seal the roof seams.
10. Paint the roof.



Installation of corrugated metal sheet roofing.

The standard lengths for corrugated roofing are 8, 10, and 12 feet. The width varies greatly, depending on the style of the roofing. The width is measured simply straight across the top of the sheet, from edge to edge, to indicate coverage width of the sheet. It does not follow peaks and valleys of the corrugate. The two most common widths are 26 and 39 inches. Other standard width include 24 and 39 inches.
The other important measurement for corrugated roof sheet is thickness. This is in gauges, with a lower number indicating a thicker sheet, and higher number indicating inner one. Standard corrugated roofing metal gauges include 18, 20, 22, 24 and 26 gauge.

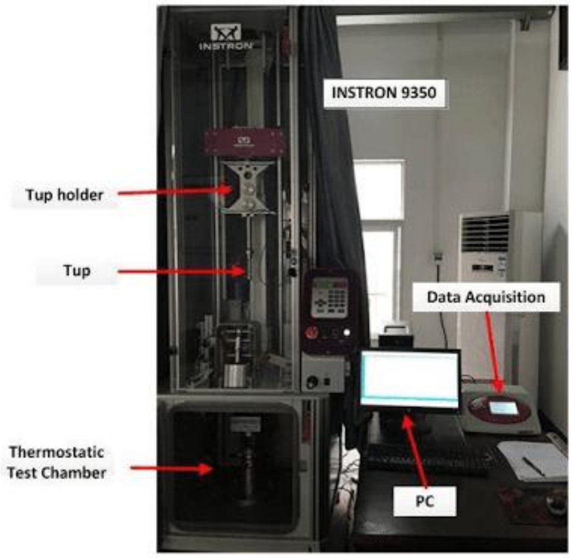
Corrugated metal sheet roofing.

II. EXPERIMENTAL METHODOLOGY

The experimental analysis was conducted on INSTRON CEAST 9350. The CEAST 9350 is a floor standing impact system designed to deliver 0.59 to 757 J or up to 1,800 J with optional high energy system. The CEAST 9350 works with impact software and data acquisition system. The details of the INSTRON CEAST 9350 is as follows:

Sr.No.	Specifications	Range
1.	Energy	0.59 to 1800 J
2.	Speed	0.77 to 24 m/s
3.	Drop Height (Simulated)	0.03 to 29.4 m

The machine is equipped with weighing system that measures the total weight of the falling mass and tup inserts. Also the specimen feeding system is equipped to perform tests in automatic cycle within the environmental chamber. It also has an environmental chamber that can cool specimen to -70 or heat specimen to + 150 degree Celsius. It is also equipped with high energy configuration setup and an automatic lubrication system eliminates friction effects between the tup insert and the test sample. Also it has the anti-rebound system that can catch the crosshead-preventing it from hitting the sample second time



Setup of INSTRON CEAST 9350

III. THEORIES OF FAILURE

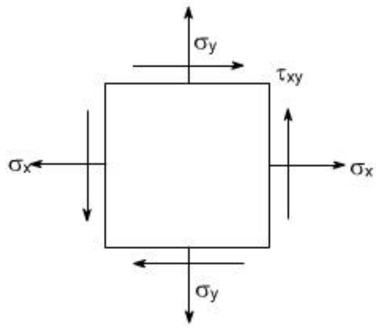
These are five different theories of failures which are generally used

(a) Maximum Principal stress theory (Due to Rankine)
(b) Maximum shear stress theory (Guest - Tresca)
(c) Maximum Principal strain (Saint - venant) Theory
(d) Total strain energy per unit volume (Haigh) Theory
(e) Shear strain energy per unit volume Theory (Von – Mises & Hencky)

In all these theories we shall assume.
σ_{Yp} = stress at the yield point in the simple tensile test.
σ_1, σ_2, σ_3 are the three principal stresses in the three dimensional complex state of stress systems in order of magnitude.

(a) Maximum Principal stress theory:
This theory assume that when the maximum principal stress in a complex stress system reaches the elastic limit stress in a simple tension, failure will occur.
Therefore the criterion for failure would be
$\sigma_1 = \sigma_{yp}$
For a two dimensional complex stress system σ_1 is expressed as

$$\sigma_1 = \frac{\sigma_x + \sigma_y}{2} + \frac{1}{2}\sqrt{(\sigma_x - \sigma_y)^2 + 4.\tau_{xy}^2}$$
$$= \sigma_{yp}$$



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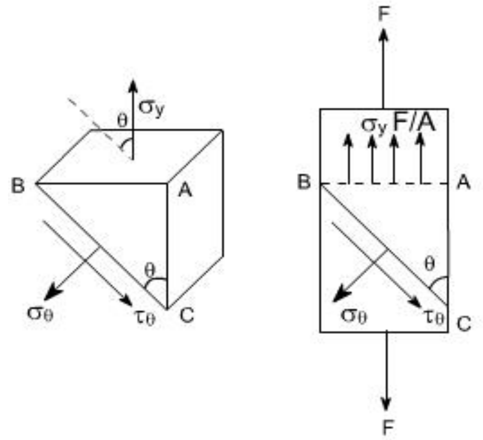
Where σ_x, σ_y and σ_{xy} are the stresses in the any given complex stress system.

(b) Maximum shear stress theory:

This theory states that the failure can be assumed to occur when the maximum shear stress in the complex stress system is equal to the value of maximum shear stress in simple tension.

The criterion for the failure may be established as given below:

For Simple Tension Case



$$\sigma_\theta = \sigma_y \sin^2\theta$$

$$\tau_\theta = \frac{1}{2}\sigma_y \sin 2\theta$$

$$\tau_\theta\big|_{max^m} = \frac{1}{2}\sigma_y \quad \text{or}$$

$$\tau_{max^m} = \frac{1}{2}\sigma_{yp}$$

whereas for the two dimentional complex stress system

$$\tau_{max^m} = \left(\frac{\sigma_1 - \sigma_2}{2}\right)$$

where σ_1 = maximum principle stress

σ_2 = minimum principal stress

$$\text{so} \quad \frac{\sigma_1 - \sigma_2}{2} = \frac{1}{2}\sqrt{(\sigma_x - \sigma_y)^2 + 4\tau^2 xy}$$

$$\frac{\sigma_1 - \sigma_2}{2} = \frac{1}{2}\sigma_{yp} \Rightarrow \sigma_1 - \sigma_2 = \sigma_y$$

$$\Rightarrow \sqrt{(\sigma_x - \sigma_y)^2 + 4\tau^2 xy} = \sigma_{yp}$$

becomes the criterion for the failure.

(c) Maximum Principal strain theory:

This Theory assumes that failure occurs when the maximum strain for a complex state of stress system becomes equals to the strain at yield point in the tensile test for the three dimensional complex state of stress system.

For a 3 - dimensional state of stress system the total strain energy U_t per unit volume in equal to the total work done by the system and given by the equation

$$U_t = 1/2\sigma_1 \in_1 + 1/2\sigma_2 \in_2 + 1/2\sigma_3 \in_3$$

substituting the values of $\in_1, \in_2$ and $\in_3$

$$\in_1 = \frac{1}{E}\left[\sigma_1 - \gamma(\sigma_2 + \sigma_3)\right]$$

$$\in_2 = \frac{1}{E}\left[\sigma_2 - \gamma(\sigma_1 + \sigma_3)\right]$$

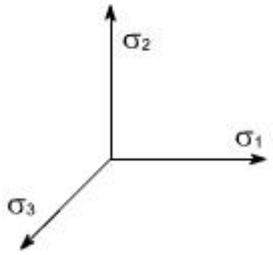
$$\in_3 = \frac{1}{E}\left[\sigma_3 - \gamma(\sigma_1 + \sigma_2)\right]$$

Thus, the failure criterion becomes

$$\left(\frac{\sigma_1}{E} - \gamma\frac{\sigma_2}{E} - \gamma\frac{\sigma_3}{E}\right) = \frac{\sigma_{yp}}{E}$$

or

$$\boxed{\sigma_1 - \gamma\sigma_2 - \gamma\sigma_3 = \sigma_{yp}}$$



(d) Total strain energy per unit volume theory:

The theory assumes that the failure occurs when the total strain energy for a complex state of stress system is equal to that at the yield point a tensile test.

$$\frac{1}{2E}\left[\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - 2\gamma(\sigma_1\sigma_2 + \sigma_2\sigma_3 + \sigma_3\sigma_1)\right] = \frac{\sigma_{yp}^2}{2E}$$

$$\sigma_1^2 + \sigma_2^2 + \sigma_3^2 - 2\gamma(\sigma_1\sigma_2 + \sigma_2\sigma_3 + \sigma_3\sigma_1) = \sigma_{yp}^2$$

It may be noted that this theory gives fair by good results for ductile materials.

(e) Maximum shear strain energy per unit volume theory:

This theory states that the failure occurs when the maximum shear strain energy component for the complex state of stress system is equal to that at the yield point in the tensile test.

$$\frac{1}{12G}\left[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2\right] = \frac{\sigma_{yp}^2}{6G}$$

Where G = shear modulus of regidity

$$\left[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2\right] = 2\sigma_{yp}^2$$

As we know that a general state of stress can be broken into two components i.e.,

(i) Hydrostatic state of stress (the strain energy associated with the hydrostatic state of stress is known as the volumetric strain energy)

(ii) Distortional or Deviatoric state of stress (The strain energy due to this is known as the shear strain energy)

As we know that the strain energy due to distortion is given as

$$U_{distortion} = \frac{1}{12G}\left[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2\right]$$

This is the distortion strain energy for a complex state of stress; this is to be equaled to the maximum distortion energy in the simple tension test. In order to get we may assume that one of the principal stress say (σ_1) reaches the yield point (σ_{yp}) of the material. Thus, putting in above equation $\sigma_2 = \sigma_3 = 0$ we get distortion energy for the simple test i.e.

$$U_d = \frac{2\sigma_1^2}{12G}$$

Futher $\sigma_1 = \sigma_{yp}$

Thus, $\boxed{U_d = \frac{\sigma_{yp}^2}{6G}}$ for a simple tension test.

IV. SIMULATION

The result of tested specimens is as follows. The simulation 1 has GI sheet as test specimen.

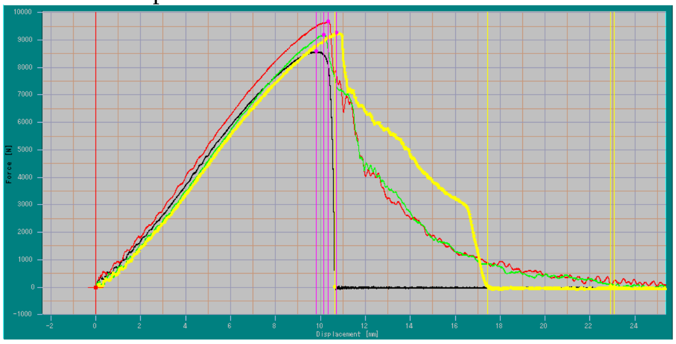
Sr.No.	Impact Energy (J)	Peak Force (N)	Peak Energy (J)	Total Energy (J)
1.	50 J	8588.22 N	45.233 J	51.26 J
2.	203.28 J	9668.80 N	53.768 J	79.86 J
3.	150.0 J	9177.88 N	47.306 J	74.95 J
4.	80 J	9279.45 N	51.403 J	82.96 J

Tested GI Specimen results

The specimen used for the test was 18 gauge thickness. Four GI specimen was been tested on INSTRON CEAST 9350. The detailed report is been tabulated as above. The first specimen was tested for 50 J of energy, the peak force obtained was 85882.22 N, and at this energy level the material showed elastic deformation. Further for next two readings the specimen raptured under loading condition, which clearly indicates that the specimen was unsafe during the impact loading conditions. The final impacted also shows elastic deformation. Thus it is clear from the impact energy values the material (GI Sheet) is safe within limits 50 J to 80 J of energy respectively.

Tested GI Sheets.

The force- displacement curve obtained was as follows:



V. RESULT & CONCLUSION

From the graph it is clear that specimen 1 and specimen 2 is within safe limits beyond the results of the specimen 2 i.e. beyond 80 J of energy the material will start its plastic deformation respectively.

VI. CONCLUSION

Nearly 80% of the rural population in India could not afford adequate roofing. Due to economic price and better reliability corrugated metal roofing are utilized on large scale in rural areas of India. It is very important to have a detail of the energy absorption rate by the corrugate metal sheet roofing. The large scale population resides in the metal sheet roofing, as per the safety is concerned. The metal sheet roofing must be tested under energy parameters to ensure the reliability of the metal sheet roofing. To ensure the optimum design of the metal sheet roofing the energy absorption is the major parameters in the analysis of the material.

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