Weight Optimization of Salt Spray Testing Chamber Frame

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***Abstract*— Salt spray test chamber comprises of a test specimen mounted in it & secured in a tightly closed space for testing under corrosive environmental conditions. A fog assembly consisting of nozzle and valve is used to control and adjust the velocity and quantity of salt mixed water spray. The test specimen kept inside the inner tank is exposed to corrosive conditions. Thus we can obtain performance of specimen under the desirable corrosive conditions. We have optimized the weight of a 900mm×450mm×450mm salt spray test chamber. The working temperature range for our salt spray test chamber is from ambient temperature upto $50^\circ C$. The company is presently using stainless steel frame for inner tank support. We have changed the material from stainless steel to Hard PVC (Polyvinyl Chloride).Thus we have tried to use possible optimum solution for the design and manufacturing process, thereby we have reduced weight and simultaneously cost also.**

***Keywords* — Salt spray, corrosion, tank, stainless steel, polyvinyl chloride (PVC) etc.**

I. Introduction

The main aim of our project is to optimize the weight of the Salt spray testing chamber frame and to modify the joining method of the structural members of the frame.

Salt spray testing chamber is used for corrosion testing of components which have their applications in humid and corrosive environment, e.g.

- Marine applications
- Chemical Process industry
- Underground electric wires
- Automobile applications
- Military applications

Fig 1. Salt spray testing chamber

II. WORKING

The component to be tested is loaded in the inner tank of salt spray testing chamber with the help of hanging rods, then the door is closed and the component is bombarded with the salt spray for a definite amount of time specified as per the requirement. It's technical specification is given in below table:

Test space capacity	120-420 litres
Temperature range	$0^\circ C$ to $50^\circ C$

Temperature Accuracy	± 1°C
Fog Collection	0.2 to 5 ml per hour
Power Supply	415 ± 5% Volts, 3 Phase, Frequency 50 Hz
Standard Used	IS 9000, IS 6910, ASTMB 117, JIS 2371 CASS

III. COMPONENTS USED IN SALT SPRAY CHAMBER

There are number of different components required for satisfactory working of salt spray chamber, some of them are discussed below

A. Inner Tank:

Inner tank is the space, where actual testing of the component's corrosion resistance is carried out. It also encloses the Spray nozzle assembly from which the salt solution is sprayed on the component to be tested. The size of inner tank is designed such that continuous recirculation of salt spray fog is maintained in the vicinity of component. The base of inner tank is slightly slanted to allow drainage of used fog. It also has wet bulb & dry bulb thermometer. Inner tank is made up of FRP (Fiber glass Reinforced Plastic). FRP is used because it is light weight and it has high corrosion resistance.

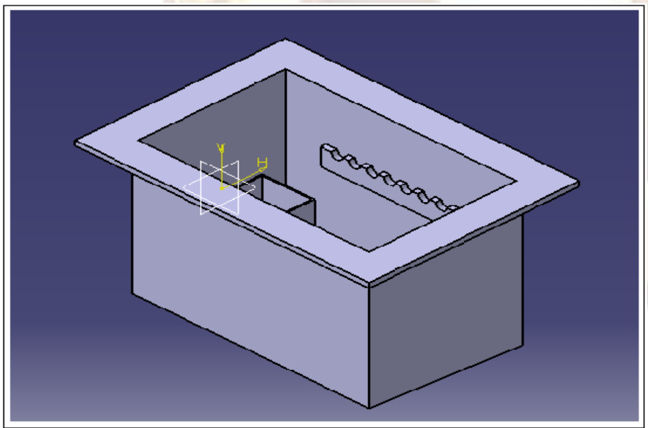


Fig 2. Inner tank

B. Electric Boiler:

An electric boiler is a type of boiler where the steam is generated using electricity, rather than through the combustion of a fuel source.

C. Solenoid Valve:

It is an electromechanical valve for the use with liquid or gas.

D. Filter:

Inline filter is used to remove the dirt coming from the water and salt solution tank.

E. Thermometers:

Inner tank consist of Dry bulb as well as wet bulb thermometers.

F. Pneumatic Regulator:

Controls the pneumatic pressure. The door of salt spray chamber is operated pneumatically.

G. Water Level Indicator:

It is used to indicate water level in the water tank.

H. pH Indicator:

A pH meter is an electronic instrument measuring the pH (acidity or alkalinity) of a liquid (though special probes are sometimes used to measure the pH of semi-solid substances). A typical pH meter consists of a special measuring probe (a glass electrode) connected to an electronic meter that measures and displays the pH reading.

I. Spray Nozzle Pressure Gauge:

It indicates the pressure of the jet released from nozzle and hence accordingly can be controlled as per the requirement.

J. Timer:

A timer is a specialized type of clock.

K. Electric Panel:

It consist of number of switches, relays, fuses, valves etc. e.g. water level control valve -if the water level in the water tank falls below minimum level it will signal the operator.

It is used for the overall functioning of salt spray chamber.

Location: It is located at right side of the salt spray chamber.

Fig 3. Electric panel

L. *Control Panel:*

It consists of numerous switches from where the operator can control overall functioning of chamber. Like-temperature control, time control, opening and closing of the doors, etc.

Location: It is located at top right hand side of the chamber

Fig 4. Control panel

IV. DESCRIPTION OF PRESENT FRAME

The frame is most integral part of the chamber over which all the components are mounted. The present frame used by the company is made up of SS304 (Stainless Steel), of square tube Cross section having dimensions 40mm×40mm×1.62mm..

The base of the frame is maintained of SS 304 material to meet strength and rigidity requirements, while the upper structural members are changed to PVC.

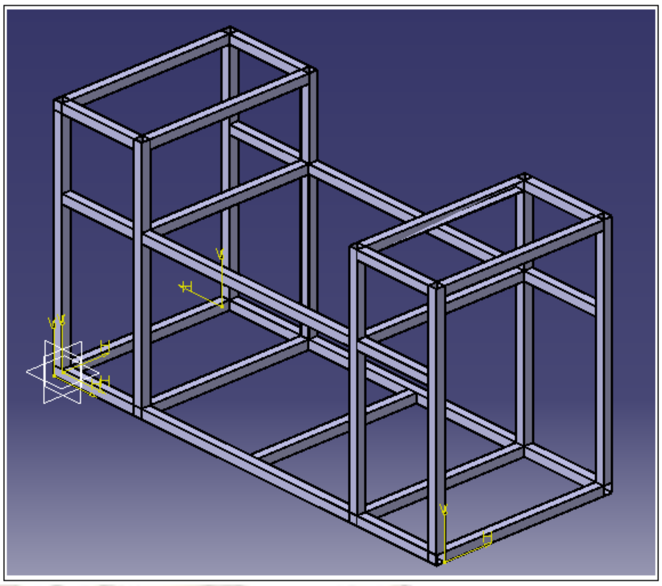


Fig 5. Present frame of SS304

A. *Weight and Cost of Present Frame:*

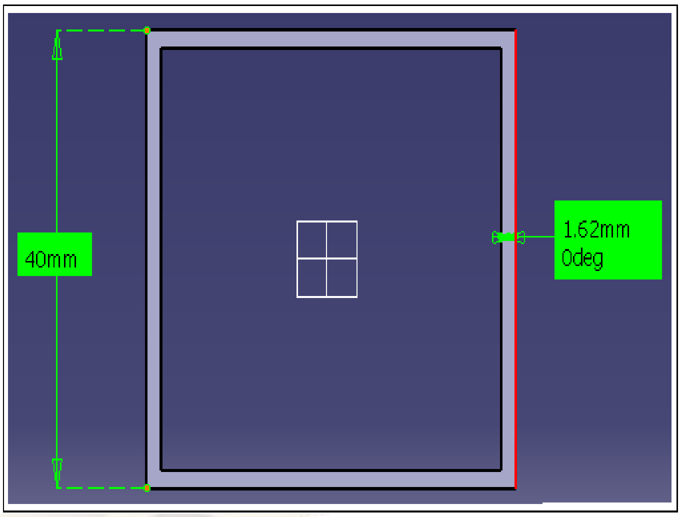


Fig 6. Cross section of present frame

Cross sectional area of existing square tube is (A) = 2.4870 $\times 10^{-4}$ m^2.

Total length of square pipe required to built one frame (L) = 27.76 m.

Density of Steel is (ρ) = 8050 kg/ m^3.

Sut of stainless steel = 505 N/mm^2

$E=1.95\times10^5$ N/mm^2.

W (weight) = 545.14 N

Cost of stainless Steel considered is = Rs. 240/kg.

Therefore,

Total Cost of Frame material is = 55.57 × 240= Rs. 13400/-

B. ***Constraints given by Company:***

1. Factor of safety = 3
2. Maximum weight acting on inner frame = 590 N
3. Maximum allowable deflection for structural member= 0.5mm
4. To change the material from SS304 to PVC.

V. DESIGN AND ANALYSIS OF SQUARE SHAPE PVC FRAME

A. ***Material selection for Pipe:***

Cost of square shape SS304 pipe was high, therefore we decided to change the material from stainless steel to PVC. Polymer has light weight and high corrosion resistance.

There are different types of polymer such as
POLY VINYL CHLORIDE (PVC)
POLY VINYL FLURIDE (PVF)
POLY VINYLI DENE FLUORIDE (PVDF)

From the above selected material PVF cannot be used because it is available only in the form of film and cannot be injection moulded.

PVDF also is available in the form of granules and powder, hence cannot be used as material for frame pipe.

PVC can be moulded in the form of pipe, and available in various sizes.

There are two types of PVCs;
1. Soft PVC
2. Hard PVC

We have selected Hard PVC because it has more tensile strength than soft PVC.

B. ***Design of PVC Frames:{1}{2}{3}***

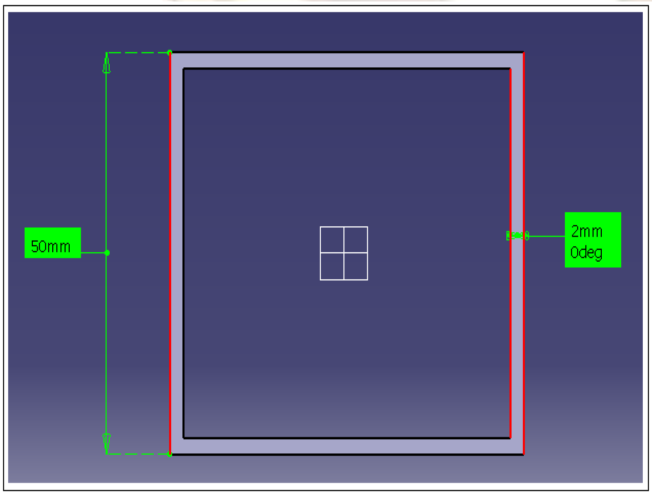


Fig 7. Square shape PVC cross section

The PVC material has Ultimate tensile strength $= 55\ N/mm^2$

Consider Factor of Safety FOS = 3

Therefore Allowable tensile strength $\sigma_{all} = \frac{55}{3}$

Therefore $\sigma_{all} = 18.33\ N/mm^2$

The moment of inertia at X-X axis,

$I_{xx} = \frac{50 \times 50^3 - 46 \times 46^3}{12}$

$I_{xx} = 147712\ mm^4$

The allowable bending moment is given by,

$$M = \frac{\sigma \times I}{y}$$

$$M = \frac{18.33 \times 147712}{25}$$

$M_{allow} = 108302.43$ Nmm

Case I Considering the longest span for the member

For l = 1110mm

$M_{ends} = \frac{w \times l^2}{12}$

$= \frac{0.2651 \times 1110^2}{12}$

$M_{ends} = 27268.2$ Nmm

M_{center} maximum bending moment is given by,

$M_{center} = \frac{w \times l^2}{24}$

$M_{center} = \frac{0.2651 \times 1110^2}{24}$

$M_{center} = 13609.57$ Nmm

$M_{center} < M_{ends} < M_{allowable}$

Hence design is safe for bending moment

$M_{allowable} = \frac{w_{allowable} \times l^2}{12}$

$w_{allowable} = \frac{108302.43 \times 12}{1110^2}$

$w_{allowable} = 2.109$ N/mm.

But $w_{existing} = 0.2651$ N/mm

$W_{existing} < w_{allowable}$

δ existing$= \frac{0.2651 \times 1110^4}{384 \times 4000 \times 147712}$

δ existing = 1.77 mm

Maximum deflection allowed is 0.5 mm. So to reduce the deflection we added one extra column at the center of 1110 mm span.

Case II

l= 555mm,

Mends $= \frac{w \times l^2}{12}$

$= \frac{0.2651 \times 555^2}{12}$

Mends = 6804.78 Nmm

M_{center} maximum bending moment is given by,

$M_{center} = \frac{w \times l^2}{24}$

$M_{center} = \frac{0.2651 \times 555^2}{24}$

$M_{center} = 3402.39$ Nmm

$M_{center} < M_{ends} < M_{allowable}$

Hence design is safe for bending moment,

$$M_{allowable} = \frac{w_{allowable} \times l^2}{12}$$

$$w_{allowable} = \frac{108302.43 \times 24}{555^2}$$

$$w_{allowable} = 8.43 \text{ N/mm.}$$

But, $w_{existing} = 0.2651$ N/mm

$$W_{existing} < w_{allowable}$$

$$\delta \text{ existing} = \frac{0.2651 \times 555^4}{384 \times 4000 \times 147712}$$

$$\delta \text{ existing} = 0.1108 \text{ mm}$$

$$\delta \text{ existing} < \delta \text{ allowable}$$

Hence design is safe for deflection, for beam of span 555mm as deflection of beam is within the company's given constraint of 0.5mm.

Case I: Analysis was carried out considering the end joining details for the members

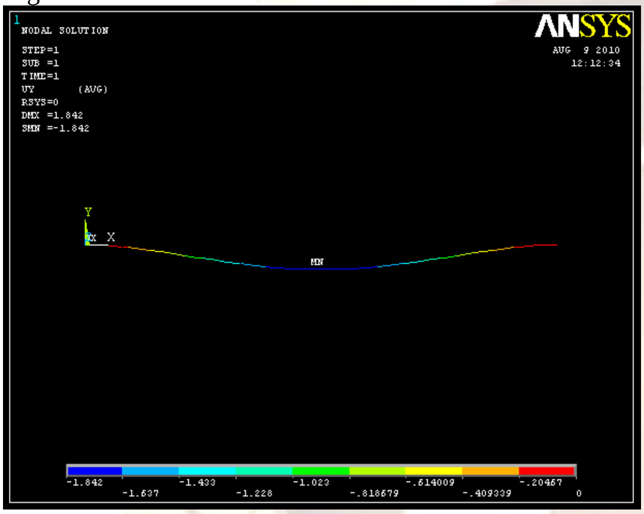


Fig 8. Maximum deflection of PVC beam of span 1110 mm

The deflection is coming 1.82 which is above 0.5 mm. The deflection is not permissible as per the requirement of company.

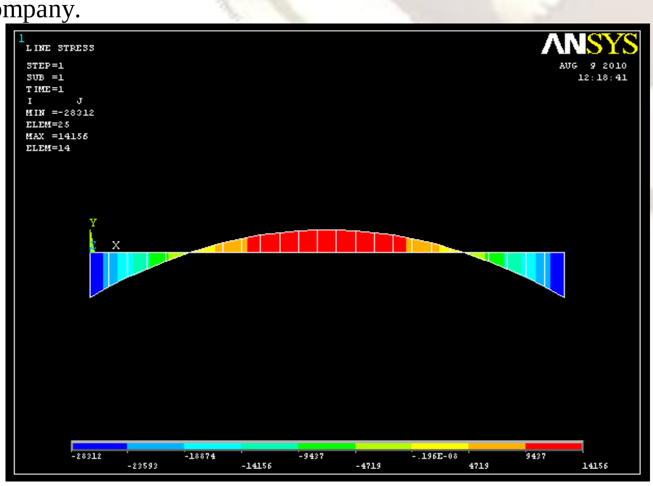


Fig 9. Bending moment analysis of PVC beam of span 1110 mm

From the above figure we can say that the bending moment is coming under limit, so the stresses coming on the beam is not crossing the allowable stress value. From this we say that the beam is safe according to bending moment but according to deflection it is not safe, so from this we conclude that the beam of PVC of span 1110mm is not safe.

Case II : Additional support was provided thus reducing the span and the analysis was carried out

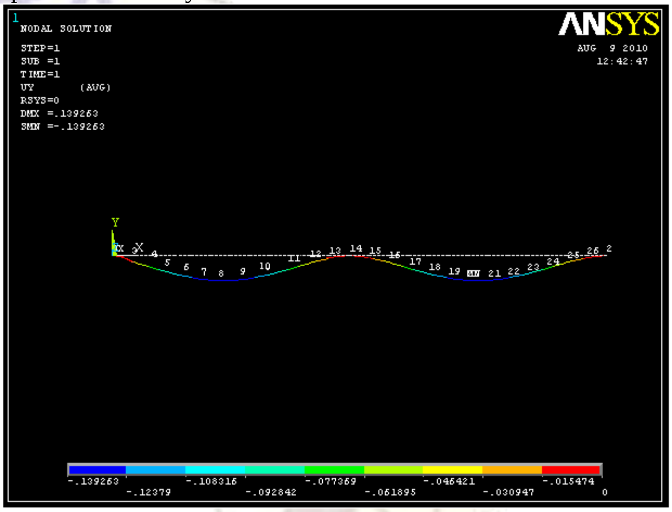


Fig 10. Maximum deflection of PVC beam of span 555 mm

Now from above figure we can say that the beam with the central column support is not crossing the deflection limit, so the beam is coming safe by analytically & theoretically.

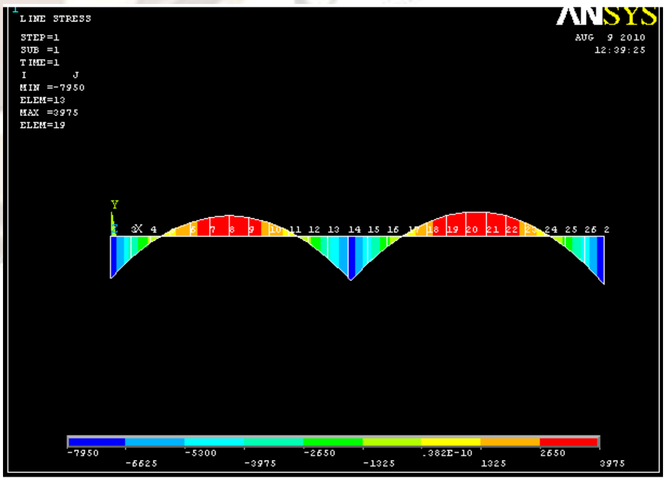


Fig 11. Bending moment analysis of PVC beam of span 555 mm

The deflection of beam is coming under the limit, but it is equally important to check the valve of bending moment analytically, so from above figure we can say that the bending moment is safe analytically, from above figure we can say that the bending moment is not crossing the maximum value, and hence the stresses coming on the beam is less than allowable stress, so the beam with central column support is safe with respect to deflection and bending moment.

C. ***Comparison of Beams of different span:***

Cases	Allowable Bending Moment (Nmm)	Actual Bending Moment (Nmm)	Allowable Deflection (mm)	Actual Deflection (mm)
Case I (1110 mm)	108302.43	27268.2	0.5	1.77
Case II (555 mm)	108302.43	6804.78	0.5	0.11

Table 1. Comparison of beams of different span

The deflection by using beam of 1110 mm was coming 1.77 mm which is above the permissible value of 0.5 mm. The deflection by using beam of 555 mm span is coming 0.11mm which is within the permissible value .Beam of 555 mm span was considered safe.

D. ***Analysis of base frame SS 304:***

The Stainless steel base frame was analysed for deflection.

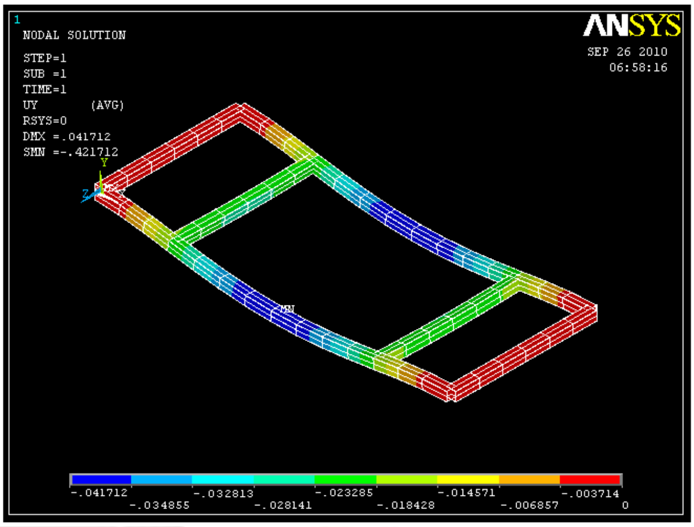


Fig 12. Deflection of base frame SS304

The base frame is supported by 4 wheels at the 4 corners each. The maximum deflection coming is 0.04 mm. Therefore, the base frame can successfully withstand the load acting on it.

E. ***Weight and cost of square PVC Frame with SS 304 base:***

Cross Sectional Area (A) = 3.84×10^{-4} m^2.
Total Length required (L) = 20.28 m.
Density of PVC (ρ) = 1380 kg/ m^3.
W_1 = 105.36 N
Weight of base frame,
Cross Sectional Area (A) = 0.196×10^{-3} m^2.
Total Length required (L) = 6.84 m.
Density of steel (ρ) = 8050 kg/ m^3.
W_2 = 105.95 N
Weight of whole frame
$W = W_1 + W_2$
W = 211.3 N .i.e. 21.54 kg.

VI. PROPOSAL FOR PVC ANGULAR CROSS SECTION FRAME

i. PVC 'L' shaped cross-sectional members were considered in place of square PVC cross-section. Strength and deflection for L shape were checked and found within limits with strength of square cross-section coming as twice (2.296 times) that of L cross-section.{4}

ii. For joining of L shaped cross-section members, corner plates are required as shown. Considering the complexity and additional cost involved, it was decided to go for square PVC pipe.

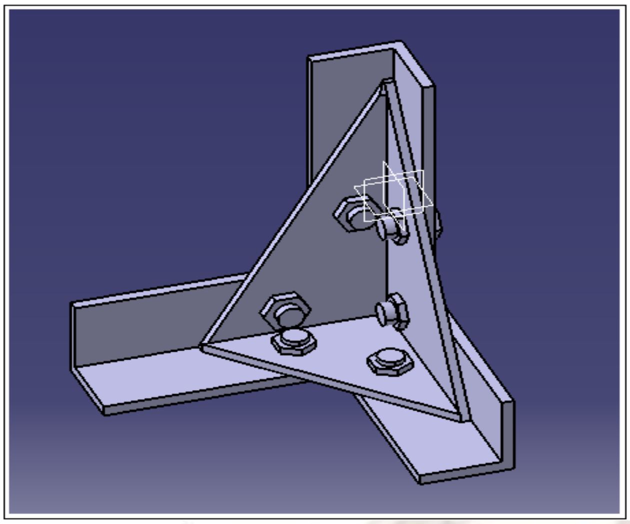
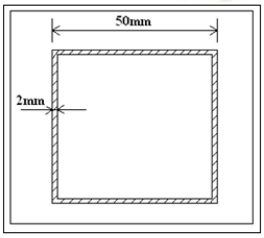
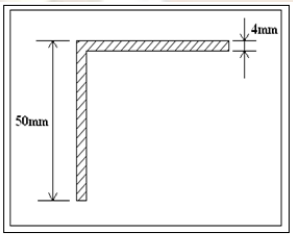


Fig 13. Joining method for 'L' shape PVC Frame

A. *Strength comparison of both frames:*





SQUARE SHAPE PVC
$I = 147712 \text{ mm}^4$

'L' SHAPE PVC
$I = 92607.993 \text{mm}^4$

VII. BUCKLING ANALYSIS OF SQUARE SHAPE PVC FRAME{3}

Buckling occurs in vertical columns which are subjected to load acting on them along vertical length, in our case vertical column has length 660 mm. We have assumed that the columns are fixed from both ends.

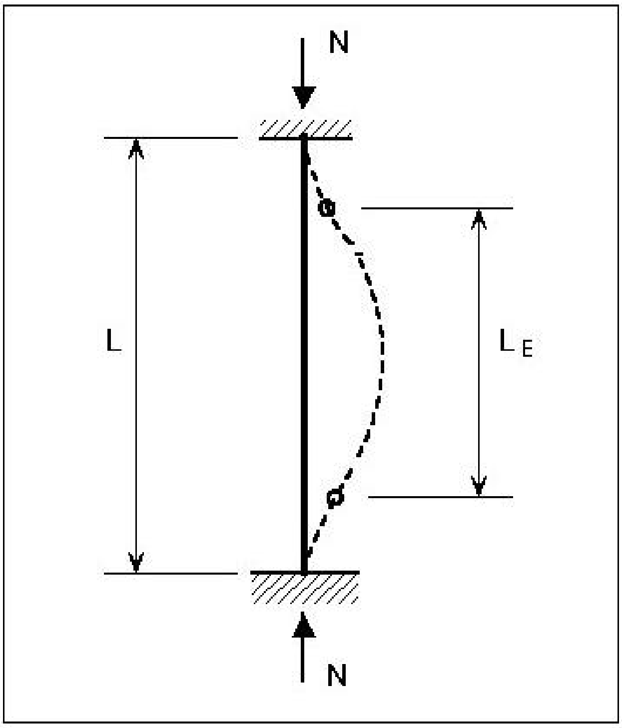


Fig 14. Column stressed under buckling

Actual length of vertical column L = 660 mm.
For fixed columns value of k = 0.6
Effective length Le is,
Le = L × k
Le = 660 × 0.6
Le = 396 mm

A load of 60 kg acting on 4 columns, hence each column will bear 15 kg load,

Therefore, w = 15 kg. = 147.15 N.
$E = 4000 \text{ N/mm}^2$.
Cross sectional area of column is,
$A = 50^2 - 46^2$
$A = 384 \text{ mm}^2$.
$I = 147712 \text{ mm}^4$.

N= 3

$$r_{min} = \sqrt{\frac{I}{A}}$$

$$r_{min} = \sqrt{\frac{147712}{384}}$$

r_{min} = 19.61 mm.

$$\text{Slenderness ratio} = \frac{Le}{r_{min}}$$

$$= \frac{396}{19.61} = 20.19$$

$$P_{max} = \frac{\pi^2 \times E \times A}{N \times \frac{Le}{rmin}}$$

$$P_{max} = \frac{\pi^2 \times 4000 \times 384}{3 \times \frac{396}{19.61}}$$

P_{max} = 13.14 KN

P_{actual} = 147.15 N < 13.14 KN As $P_{max} > P_{actual}$, hence the design is safe in buckling also.

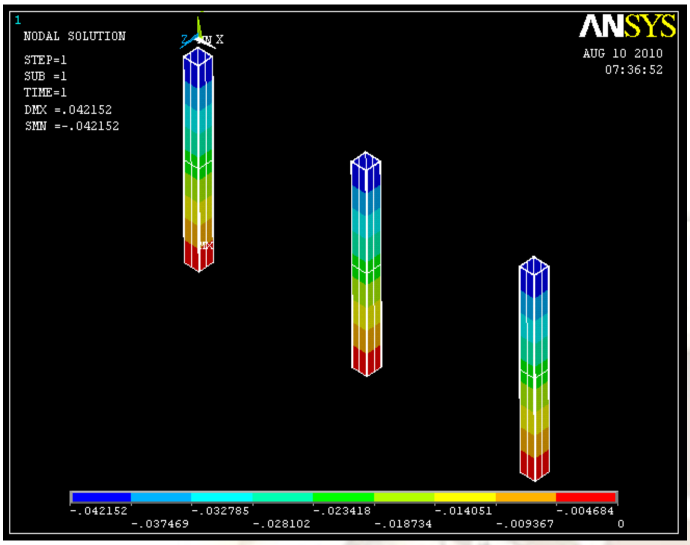


Fig 15. Buckling of vertical column

But the main part of frame is its column support it should not buckle due to axial load. From analytical method we can see the effect of load on columns; so from above figure, we can say that the buckling of beam is negligible so the column is coming safe.

VIII. SELECTION OF JOINING METHOD

For the joining of the members threaded joints and PVC welded joints were compared and threaded joints were preferred.{5}

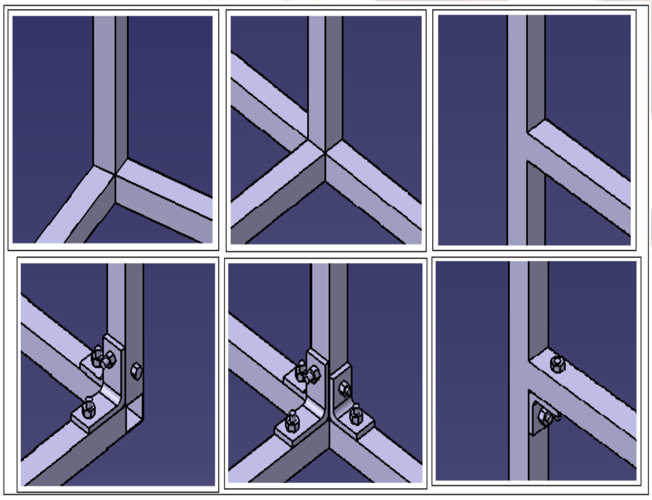


Fig 16. Comparison of welded and threaded joint

IX. DESIGNED FRAME

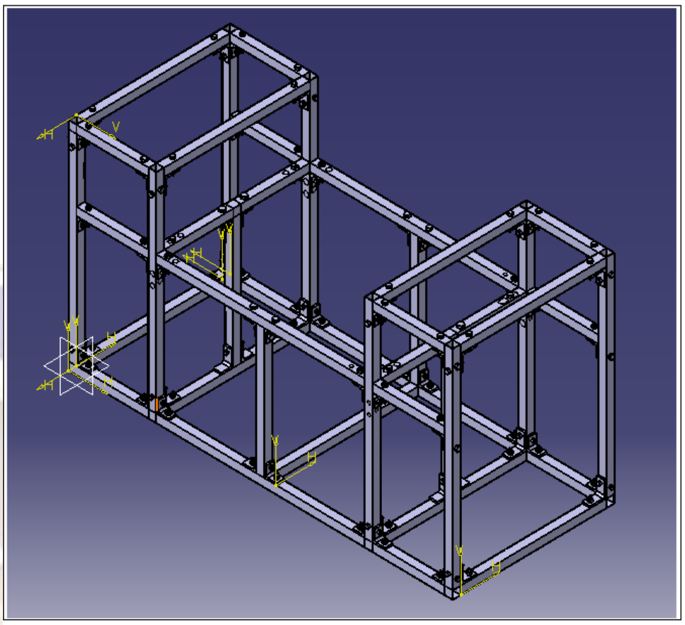


Fig 17. Designed frame

X. RESULT TABLE

PART	SIZE	QTY.	WT.	COST* /KG	COST (RS)
PVC frame	50×50×2	20.28 m	10.74	67	720
Base frame SS304	50×50×1	6.84m	10.8	240	2600
Corner Plate (Al)	80×80×9	16 Nos.	2.70	130	350
Corner Plate (Al)	60×60×3	72 Nos.	3.40	130	440
Nuts & Bolt SS304	M8	28 Nos	-	-	-
Total cost of frame					4110

* Rates considered are for comparison purpose only.

XI. CONCLUSION

1. Weight of the frame has been reduced from 55.57 kg to 27.64 kg by replacing stainless steel by PVC.
2. Simultaneously cost also reduced by about 55%.
3. Modified design of Salt Spray Testing Chamber is under implementation in the company.

XII. REFERENCES

[1]. Design data book by K. Achchagaman

[2]. Design of machine element by V. B. Bhandari

[3]. Strength of Materials by Ramamrutam

[4]. Metallurgy by J. K. Shaikh

[5]. Inputs from Kasco Industries Pvt.Ltd.

[6]. www.azom.com

[7]. www.wikipedia.com

[8]. www.howstuffworks.com

[9]. www.engineeringtoolbox.com