Sample Report for Storage Tank
Shell Structural Profile & Bottom Profile Survey

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<td>MOHAMED RAUB</td>
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<td>SANJAY BOSE</td>
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1. **Execution Summary**

Survey had to be carried out on (Tank no); vertical Butt welded mild steel cylindrical tank, with a floating roof.

On behalf of our end client, (Company Name) we have performed a survey of the tank to provide data to assist in determining the compliance of tank with API Standard 653, Appendix B Shell Settlement specifications and Roundness.

The engineers who performed the onsite survey on (Date) were Mr. Sanjay Bose & Mr. Mohamed Raub.

This report should be read in conjunction with API 653 Appendix B.

The API 653, Appendix B standard allows the operator to interpret settlement data, particularly the determination of floor edge settlement break-over points and the nomination of statistical outlying data for shell settlement in determination of the plane of rigid tilt and the tank shell deflection.

We have exercised such judgment in good faith and provide illustrations of our working in this report; and we have processed the data for the convenience of engineering personnel assessing the tank against the API 653B standard. The ultimate responsibility therefore lies with the engineers in accepting the information in this report and its suitability for deciding upon the condition of the tank consequently, we are receptive to any requests from our client to re-process the tank data in accordance with their differing interpretation of the API 653B standard.

The Standard acknowledges that the tank’s previous service history may be considered in evaluating many of the aspects of settlement.

We cannot comment whether the apparent settlement of the tank represents the as-built condition or is settlement since construction. The API 653 settlement specifications assume the current condition to have developed from a purely symmetrical tank, and as such should be viewed as a worst-case evaluation.

Other than by the methods described in API Standard 653 Appendix B, we do not attempt to calculate the tank shell stresses that may be generated by tank settlement.
2. Person To Contact

CLIENT:

CONTRACTOR:

Global Remote

E | india@global-remote.net
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Person to Contact: Mr. Sanjay Bose
Technical In-charge | Tank Survey & Calibration Division
T: +974 3347 1069 / +91 84201 27554
E: sanjay.b@global-remote.net
3. **Applicable Codes, Standards, Specification**

4. MECHANICAL DATA Sheets’ (As Built)

4. **Abbreviation**

- API - American Petroleum Institute
- ISO - International Standard Organization
- Smax - Permissible out-of-plane settlement
- L - Arc length between measurement points
- Y - Yield strength of the shell material
- E - Young’s Modulus
- H - Tank height
- M - Meters
- mm - Millimeters
5. **Tank Description**

Client : 

Location : 

Tank Number : 

**Material of Construction** : Mild Steel

**Number of Shell Courses** : Eight (08)

**Method of Construction** : Welding

**Product Storage** : Crude Oil

**Service** : Off-Stream

**Type of Roof** : Floating Roof


**Evaluation Carried out by** : Mr. Sanjay Bose - Surveyor

**Date of Survey** : 

**Inspection/Survey Carried out** : Tank Shell Settlement
Tank out-of roundness survey.
Tank Verticality.

**Values Considered for evaluation** : 
- Height: 21.921 M
- Diameter: 92.000 M
- Arc Length (L): 9.639 M
- Yield Strength (Y): 30000
- Young’s Modulus (E): 29000000
6. Shell Roundness Survey Evaluation

A survey of tank shell was performed in accordance with API, to obtain verticality data at two heights of each strake (measured with optical equipment along 30 vertical stations around the tank exterior) and a tank reference circumference corresponding with the strake 1 upper section verticality reading.

To provide a report on the roundness of the tank shell, we have also determined the internal radii at each measurement station at 500 millimeters above the base of the tank shell.

The internal radii are derived from laser ranging (offset) measurements taken outside from the tank from a fixed point to each station around the lower section of 1st Course. These readings are adjusted using the tank shell verticality measurements to give an equivalent reading at 500 millimeters above the tank base. The tank centroid is computed from the adjusted offsets and the radius between the centroid and each measurement station calculated, as reported in the table below.

**Radii at 500 mm above tank base**

The maximum radius variation at 500 millimeters above the base of the tank shell is - 25 millimeters

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Following are the deviations between the reference radius and the radius at each individual station:

The tolerances given in API 653 Table 10.2 the max Permissible value for Radii measured at 1 ft. above the shell-to-bottom weld shall not exceed +31.75 mm (Tank Diameter (Feet) >250).

Radius tolerances measured higher than one foot above the shell-to-bottom weld the max Permissible Radius tolerances value will be three times the tolerances given in API 653 Table 10.2 which we mentioned before.
**Internal Offsets corrected for plate thickness - millimetres**

**Negative value = Tank Set IN**

* Top = 80%, Bott = 20%

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** Top = 80%, Bott = 20%**

Maximum Offset Set In = -59 mm
Minimum Offset Set Out = 63 mm

Corrected External Circumference at Reference Course 1 = 289.172 m
Corrected Internal Diameter at Reference Course 1 = 91.9603 m
Internal Radius = 45.98 m

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### Opposing station internal offsets - Calculated internal diameter - metres

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### Opposing station internal offsets - Calculated internal diameter - metres

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**Maximum Diameter:** 92.034 M  
**Minimum Diameter:** 91.893 M  
**Maximum Tank Set Out:** 74 MM  
**Maximum Tank Set In:** -67 MM
Opposing station internal offsets - metres

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Opposing station internal offsets - metres

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Ring offset graphs:

Ring # : 1 no Top & Bottom

*Not to scale, magnified for clarity
Ring offset graphs:

Ring #: 8 no Top & Bottom

*Not to scale, magnified for clarity
Offset graphs-opposite stations:

INTERNAL OFFSETS (OPPOSING STATIONS) IN MM

Station 1

- Station offsets:
  - 1st course: 0.000 m
  - 2nd course: 2.745 m
  - 3rd course: 5.493 m
  - 4th course: 8.243 m
  - 5th course: 11.000 m
  - 6th course: 13.742 m
  - 7th course: 16.500 m
  - 8th course: 19.235 m
  - 9th course: 21.921 m

- Course offsets:
  - 1st course: 91.929 m
  - 2nd course: 91.970 m
  - 3rd course: 91.958 m
  - 4th course: 91.966 m
  - 5th course: 91.979 m
  - 6th course: 91.972 m
  - 7th course: 91.951 m
  - 8th course: 91.968 m

*Not to scale, magnified for clarity
Offset graphs-opposite stations:

INTERNAL OFFSETS (OPPOSING STATIONS) IN MM

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*Not to scale, magnified for clarity*
Offset graphs-opposite stations:

INTERNAL OFFSETS (OPPOSING STATIONS) IN MM

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-13 91.957 m
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-5 91.969 m
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-1 91.970 m
1 91.977 m
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3 91.962 m
3 91.962 m
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*Not to scale, magnified for clarity
**Offset graphs-opposite stations:**

**INTERNAL OFFSETS (OPPOSING STATIONS) IN MM**

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*Not to scale, magnified for clarity*
7. Tank Verticality Evaluation

Tank verticality survey was performed in accordance with API, to obtain verticality data at two heights of each tank of the top of the shell with respect to bottom of the shell (measured with optical equipment along 30 vertical stations around the tank exterior).

The verticality evaluation was made in two different formats. One format represents the verticality value in each shell two positions with respect to the bottom of the first shell & other represents the value of the top of the tank with respect to the bottom of the tank.

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**MAXIMUM VERTICALITY SET IN = 57 mm**

**MINIMUM VERTICALITY SET OUT = -78 mm**
### Verticality value of the top of the tank with respect to the bottom of the tank.

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**Verticality Value**
-1  29  -67  -78  -4  14  -24  -31  -2  -6  -22  40  -32  -44  -53  -32  -6  39  39  8

**MAXIMUM VERTICALITY SET IN** = **40 mm**

**MINIMUM VERTICALITY SET OUT** = **-78 mm**

The maximum out-of-plumbness / verticality of the top of the shell with respect to bottom of the shell is ± 127mm.

This evaluation is done in accordance with the section 10.5.2.1 of API Standard 653.
8. Edge Settlement (API653B method)

The measurement points are connected with spline curves to produce each floor profile. Dimensions in millimetres.
Edge Settlement (API653B method)

Measurement Points (metres from shell)

0.3  0.6  1  3  4  5  7  9

Station 19

Station 20

Station 21

Station 22

Station 23

Station 24

The measurement points are connected with spline curves to produce each floor profile
Dimensions in millimetres
Edge Settlement Evaluation – API653B

API 653 Appendix B Floor Edge Settlement Evaluation Criteria

1. Tanks with larger edge settlements than $B_{\text{new}}/B_{\text{g}}$ are to be repaired, or have detailed analysis of the floor, and floor to shell junction.
2. Welds in tanks with settlement $r$ at $r$ than or equal to 75% of $B_{\text{new}}/B_{\text{g}}$ and $r$ larger than 2", are to be inspected with magnetic particle or liquid penetrant examination.
3. Tanks with settlement less than 75% of $B_{\text{new}}/B_{\text{g}}$ may be returned to service.
4. An asterix preceding an evaluation comment denotes a settlement radius that exceeds the range of the graph provided by the Standard (6 feet).

The $B_{\text{new}}/B_{\text{g}}$ value provided in the table is extrapolated from the graphs.

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<th>API 653B Evaluation Method Reference</th>
<th>Actual Settled Area Radius R (mm)</th>
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<th>Max Allowable Settled Area $B_{\text{new}}/B_{\text{g}}$ (mm)</th>
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9. Tank Shell Settlement Evaluation

Location 1 to 30 as indicated above is moving in anti-clockwise direction

API Standard 653 (B.3.2) approximation for maximum out-of-plane deflection is 18.00 mm.

The Standard suggests further assessment or repair if the deflection exceeds the permissible value.

This evaluation is done in accordance with the section B.2.2.4f of API Standard 653

The max Permissible value As per API Standard 653 Edition 2014 (section B.3.2.1) is + 24.10 mm by the following equation

\[
S_{maxft} = \frac{(L^2 \times Y \times 11)}{2[(E \times H)]}
\]

So, the tank can be used as per above mentioned value from API standard, but needs to checked for settlement at periodic interval.
10. TANK BOTTOM FLOOR PROFILE FROM CENTRE (CONE UP)

CENTRELINE

Segment 1 (0 deg)

Segment 2 (30 deg anti-clockwise)

Segment 3 (60 deg anti-clockwise)

Segment 4 (90 deg anti-clockwise)
TANK BOTTOM FLOOR PROFILE FROM CENTRE (CONE UP)

AVERAGE SHAPE OF TANK BOTTOM

CONE-UP PROFILE
(ALL DEPTH IN CM)

AVERAGE SHAPE OF BOTTOM (DEPTH FROM TANK BOTTOM)

CENTRELINE   TANK SHELL SIDE
11. Evaluation Summary

- **Tank Shell Settlement**: The maximum out-of-plane deflection is 18.0 mm.

  The max Permissible value as per API Standard 653 Edition 2014 (section B.3.2.1) is

  \[ S_{\text{max}} \text{ ft} = \frac{(L^2 \times Y \times 11)}{2[(E \times H)]} \]

  Where: \( S_{\text{max}} \text{ ft} \) is permissible out-of-plane settlement, in feet (ft);

  \( L \) is arc length between measurement points, in feet (ft);

  \( Y \) is yield strength of the shell material, in pound force per square inch (lbf/in²);

  \( E \) is Young’s Modulus, in pound force per square inch (lbf/in²);

  \( H \) is tank height, in feet (ft).

- **Tank Out-of-Roundness / Ovality**: The maximum radius variation at 300mm above the base of the tank shell is -25.0 mm.

  The tolerances given in API 653 Table 10.2 the max Permissible value for Radii measured at 1 ft. above the shell-to-bottom weld shall not exceed +31.75mm (Tank Diameter (Feet) >250).

- **Tank Out-of-Plumbness / Verticality**: The maximum Verticality value of the top of the tank with respect to the bottom of the tank is -78.0 mm & The maximum the verticality value in each shell two position with respect to the bottom of the first shell is -78.0 mm

  The maximum out-of-plumbness / verticality of the top of the shell with respect to bottom of the shell is \( \pm 127.0 \) mm.

  This evaluation is done in accordance with the section 10.5.2.1 of API Standard 653

**Reviewed & Approved By:**
REPORT: C-XX STORAGE TANK-XXXX EDGE SETTLEMENT SURVEY DURING HYDROTEST

QATAR CHEMICAL COMPANY LTD.
MESAIEED, QATAR.

August 2016

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<tbody>
<tr>
<td>PREPARED</td>
<td>MOHAMED RAUB</td>
</tr>
<tr>
<td>APPROVED</td>
<td>SANJAY BOSE</td>
</tr>
<tr>
<td>CONTROLLED COPY?</td>
<td>YES</td>
</tr>
<tr>
<td>CIRCULATION</td>
<td>IET ADMINISTRATION &amp; CLIENT</td>
</tr>
</tbody>
</table>
TANK EDGE SETTLEMENT SURVEY
(DURING HYDROTEST)

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1. Execution Summary

Edge settlement Survey on different water level (0, 20, 40, 60 & 80 percentage) during water filling and (40 & 0 percentage) during dewatering of hydro test had to be carried out on C-xxStorage Tank-xx-xxxx; vertical Butt welded mild steel cylindrical tank, with a fixed roof.

On behalf of our end client, Qatar Chemical Company Ltd.(QCHEM) we have performed a survey of the tank to provide data to assist in determining the compliance of tank with API Standard 653, Appendix B Shell Edge Settlement.

The engineers who performed the onsite survey were Mr. Sanjay Bose & Mr. Sobin Sibichen.

This report should be read in conjunction with API 653 Appendix B.

The API 653, Appendix B standard allows the operator to interpret settlement data, particularly the determination of floor edge settlement break-over points and the nomination of statistical outlying data for shell settlement in determination of the plane of rigid tilt and the tank shell deflection.

We have exercised such judgment in good faith and provide illustrations of our working in this report; and we have processed the data for the convenience of engineering personnel assessing the tank against the API 653 B standard. The ultimate responsibility therefore lies with the engineers in accepting the information in this report and its suitability for deciding upon the condition of the tank consequently, we are receptive to any requests from our client to re-process the tank data in accordance with their differing interpretation of the API 653B standard.

The Standard acknowledges that the tank’s previous service history may be considered in evaluating many of the aspects of settlement.

We cannot comment whether the apparent settlement of the tank represents the as-built condition or is settlement since construction. The API 653 settlement specifications assume the current condition to have developed from a purely symmetrical tank, and as such should be viewed as a worst-case evaluation.

Other than by the methods described in API Standard 653 Appendix B, we do not attempt to calculate the tank shell stresses that may be generated by tank settlement.
2. **Person To Contact**

**CLIENT:**

Qatar Chemical Company Ltd.,
Mesaieed Industrial City,
State of Qatar.

**CONTRACTOR:**

Person to Contact:

**Sub-Contractor:**

Inside Exploration Technologies WLL,
P.O. Box: 201763 Doha, State of Qatar.

**Person to Contact:**

Mr. Sanjay Bose
Technical In-charge | Tank Survey & Calibration Division
T: +974 3347 1069
E: sanjay.b@global-remote.net

Mr. Ginosh Abraham
Director-Middle East.
3. Applicable Codes, Standards, Specification

4. MECHANICAL DATA Sheets’ (As Built)

4. Abbreviation

- API - American Petroleum Institute
- ISO - International Standard Organization
- Smax - Permissible out-of-plane settlement
- L - Arc length between measurement points
- Y - Yield strength of the shell material
- E - Young’s Modulus
- H - Tank height
- M - Meters
- mm - Millimeters
5. Tank Description

<table>
<thead>
<tr>
<th>Client</th>
<th>Qatar Chemical Company Ltd.,</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Mesaieed, Qatar.</td>
</tr>
<tr>
<td>Tank Number</td>
<td>C-xx STORAGE TANK-xxxxxx</td>
</tr>
<tr>
<td>Material of Construction</td>
<td>Carbon Steel</td>
</tr>
<tr>
<td>Number of Shell Courses</td>
<td>Six (06)</td>
</tr>
<tr>
<td>Method of Construction</td>
<td>Welding</td>
</tr>
<tr>
<td>Product Storage</td>
<td>C-xx Product</td>
</tr>
<tr>
<td>Service</td>
<td>0, 20, 40, 60 &amp; 80% water level during Hydro test</td>
</tr>
<tr>
<td>Type of Roof</td>
<td>Fixed Dome</td>
</tr>
<tr>
<td>Evaluation Carried out by</td>
<td>Mr. Sanjay Bose - Surveyor</td>
</tr>
<tr>
<td>Date of Survey</td>
<td></td>
</tr>
<tr>
<td>Inspection/Survey Carried out</td>
<td>• Tank Edge Settlement</td>
</tr>
</tbody>
</table>

Values Considered for evaluation:

- Height: 10.800 M
- Arc Length (L): 8.245 M
- Yield Strength (Y): 30000
- Young’s Modulus (E): 29000000
6. Tank Edge Settlement Evaluation - During Hydrotest (Water filling)

<table>
<thead>
<tr>
<th>Location</th>
<th>Actual Edge Settlement (mm)</th>
<th>Settlement Value - 0% Water Level</th>
<th>Settlement Value - 20% Water Level</th>
<th>Settlement Value - 40% Water Level</th>
<th>Settlement Value - 60% Water Level</th>
<th>Settlement Value - 80% Water Level</th>
<th>Settlement Value - 40% Water Level (Dewatering)</th>
<th>Settlement Value - 0% Water Level (Dewatering)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0</td>
<td>-3.0</td>
<td>-4.5</td>
<td>-2.5</td>
<td>-3.5</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>-4.0</td>
<td>0.5</td>
<td>-1.5</td>
<td>-3.5</td>
<td>-2.5</td>
<td>-3.5</td>
<td>-3.5</td>
<td>-1.0</td>
</tr>
<tr>
<td>3</td>
<td>6.0</td>
<td>5.0</td>
<td>2.0</td>
<td>4.0</td>
<td>1.5</td>
<td>2.5</td>
<td>1.0</td>
<td>5.0</td>
</tr>
<tr>
<td>4</td>
<td>-9.0</td>
<td>-5.0</td>
<td>0.0</td>
<td>0.5</td>
<td>1.5</td>
<td>0.5</td>
<td>-4.5</td>
<td>6.0</td>
</tr>
<tr>
<td>5</td>
<td>2.0</td>
<td>-1.0</td>
<td>3.5</td>
<td>4.5</td>
<td>5.5</td>
<td>5.5</td>
<td>5.5</td>
<td>5.5</td>
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<tr>
<td>6</td>
<td>-4.0</td>
<td>0.5</td>
<td>6.5</td>
<td>4.5</td>
<td>3.5</td>
<td>3.5</td>
<td>-7.0</td>
<td>2.5</td>
</tr>
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<td>7</td>
<td>0.0</td>
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<td>-1.0</td>
<td>-0.5</td>
<td>-0.5</td>
<td>0.5</td>
<td>6.0</td>
<td>6.0</td>
</tr>
<tr>
<td>8</td>
<td>0.0</td>
<td>0.0</td>
<td>-4.0</td>
<td>6.0</td>
<td>6.0</td>
<td>-3.0</td>
<td>-6.5</td>
<td>-6.5</td>
</tr>
</tbody>
</table>

Location 1 to 8 as indicated above is moving in anti-clockwise direction.

API Standard 653 (B.3.2) approximation for maximum out-of-plane deflection is -7.5 mm.

The Standard suggests further assessment or repair if the deflection exceeds the permissible value.

This evaluation is done in accordance with the section B.2.2.4f of API Standard 653.

The max Permissible value As per API Standard 653 Edition 2014 (section B.3.2.1) is + 35.81 mm by the following equation

$$ S_{maxf} = \frac{(L^2 \times Y \times 11)}{2[(E \times H)]} $$
7. Tank Edge Settlement Evaluation

With respect to 0% water level

<table>
<thead>
<tr>
<th>Water Level</th>
<th>Settlement Value</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0%</td>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>-20%</td>
<td></td>
<td>1.5</td>
<td>2.0</td>
<td>3.0</td>
<td>-5.0</td>
<td>-4.5</td>
<td>-6.0</td>
<td>0.0</td>
<td>9.0</td>
</tr>
<tr>
<td>-40%</td>
<td></td>
<td>-0.5</td>
<td>4.0</td>
<td>6.5</td>
<td>-9.0</td>
<td>-5.5</td>
<td>-4.0</td>
<td>-0.5</td>
<td>9.0</td>
</tr>
<tr>
<td>-60%</td>
<td></td>
<td>-0.5</td>
<td>3.0</td>
<td>6.5</td>
<td>-6.5</td>
<td>-1.5</td>
<td>-6.0</td>
<td>-4.5</td>
<td>9.5</td>
</tr>
<tr>
<td>-80%</td>
<td></td>
<td>0.5</td>
<td>-2.0</td>
<td>5.5</td>
<td>-4.5</td>
<td>-4.5</td>
<td>-5.0</td>
<td>-1.5</td>
<td>11.5</td>
</tr>
<tr>
<td>-Dewatering</td>
<td></td>
<td>-4.0</td>
<td>4.0</td>
<td>4.0</td>
<td>-0.5</td>
<td>-6.0</td>
<td>-5.0</td>
<td>6.0</td>
<td>1.5</td>
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<tr>
<td>-Dewatering</td>
<td></td>
<td>-3.0</td>
<td>1.5</td>
<td>8.0</td>
<td>-6.5</td>
<td>-7.0</td>
<td>-5.5</td>
<td>2.0</td>
<td>10.5</td>
</tr>
</tbody>
</table>

In the above graph Evaluation for Settlement Survey Value in different water level is calculated with respect to 0% water level as reference.

8. Evaluation Summary

The maximum out-of-plane deflection is -7.5 mm.

The max Permissible value As per API Standard 653 Edition 2014 (section B.3.2.1) is ±35.81 mm by the following equation

\[
S_{\text{max ft}} = \frac{(L^2 \times Y \times 11)}{2 \times (E \times H)}
\]

Where: Smax, ft is permissible out-of-plane settlement, in feet (ft);
L is arc length between measurement points, in feet (ft);
Y is yield strength of the shell material, in pound force per square inch (lbf/in²);
E is Young’s Modulus, in pound force per square inch (lbf/in²);
H is tank height, in feet (ft).