Design of Offshore Structures using STAAD.Pro and STAAD.Offshore

By

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STAAD.Pro is a general purpose structural analysis and design tool that is being used to design offshore structures. STAAD.Offshore allows users create wave loading and transport loads on offshore structures. It can handle pipes, rectangular/square tubes, and open sections such as I-beams and channels, or other structural shapes by judicious selection of the wave force coefficients. A typical scenario is an offshore jacket structure as shown in Figure 1. The offshore jacket can be subjected to many types of loads including wave loads and several transport ship motions.

Figure 1: Typical jacket structures

These structures are modeled in STAAD.Pro as shown in Figure 2. Section properties can be assigned using the STAAD.Pro code based section database or the user can create user tables to define custom sections. Once the section properties and supports have been assigned, the STAAD.Pro model can be imported into STAAD.Offshore to perform the wave load generation as shown in Figure 3.

Figure 2: STAAD.Pro structural analysis model of an offshore structure
STAAD.Offshore provides the user with options to generate wave loads using eight different wave generation theories. The height of the wave and period of the waves have to be provided in STAAD.Offshore as shown in Figure 4.
The user is requested to specify the in-plane (xz plane) approach angle of the waves as shown in Figure 5.

![Figure 5: A wave approaching an offshore structure](image)

STAAD.Offshore requires the user to input the wave positions that need to be considered for the load generation. For example, in Figure 6, the user has requested STAAD.Offshore to perform wave load generation at 0° to 180° with a step of 90°. Hence STAAD.Offshore will generate three load cases (i.e. wave at 0°, 90° and 180°).

![Figure 6: User requested load generation at 0° to 180° with a step of 90°.](image)

The resultant load cases can be better visualized in STAAD.Pro. Figure 7 illustrates the STAAD.Offshore wave load cases using the STAAD.Pro interface.
Figure 7: User requested load generation at 0° to 180° with a step of 90°. The wave loads are represented as trapezoidal loads in STAAD.Pro.

There are a number of other inputs required for the wave load generation which include but are not limited to the following:

- Mudline level
- Centre of rotation of the structure
- Water depth
- Wave kinematics factor
- There is an option in the program to neglect the overturning moments at the base that are caused by the vertical forces. This allows the vertical wave force effects to be quantified.
- Wave force coefficients, drag and added mass, which can be specified independently for each member or using a member range.
- Marine growth and current velocity profiles are specified relative to the still water level, SWL, and are described by a discrete set of data points.

The wave current and wave directions can be in different directions and the combined effect is accounted for.

The Transport Load Module in STAAD.Offshore can generate inertia loads due to self weight, joint weights, member point weights, and member segmented linear varying weights based on the distance of the load point from the centre of rotation.

For example, one could find out the inertial load acting on an offshore deck or module structure due to a ship motion. Figure 8 shows the different types of ship/vessel motion parameters that can be entered in STAAD.Offshore. These motion parameters will let the user generate response inertia forces on the STAAD.Pro model. The right side of Figure 9 illustrates the inertia force diagram of the offshore deck in the STAAD.Pro model.
Motion loads can be generated in all the six degrees of freedom, DOF, and combined to form basic STAAD.Pro load cases. The DOF motions in a load case can be added or subtracted by specifying a directional load factor, e.g. -1.20, 1.0 etc, a factor greater than 1.0 would signify a correction factor being applied to the generated load.
Using directional load factors is possible to form load cases comprising of: heave + roll, or heave - roll and heave + pitch, or heave - pitch, to determine the maximum member forces at all positions within a structure.

**Figure 9:** Response of the structure due to inertia forces generated using offshore transport module

The wave loads and transport loads generated in the STAAD.Pro model can be combined with other load cases. These load combinations can be used to design the structure as per the American Petroleum Institute (API) design code. The API code is the 21st edition, Dec 2000 (but without the errata and supplements 1 and 2 of 2002 and 2005), is used as the basis of this design (except for tension stress). For tubular members, punching shear may be checked in accordance with the API RP 2A – 21th Edition Section 4. Figure 10 shows a typical design output on the right and a color coded diagram that shows the design ratios in a graphical format.

**Figure 10:** API Design results displayed in STAAD.Pro
STAAD.pro API Punching Shear Checks

STAAD.pro is capable of doing the API punching shear checks. The user has to simply follow the two-step process in the "International Codes Manual" Page 15-14 to perform the API punching shear checks.

**Step 1:** Set LEG parameter to 1.0. (i.e. give the LEG 1.0 command in the input file). Analyze the STAAD.pro input file. After running the analysis, an "APIPUN" file will be created in the project directory. This file can be opened using notepad and the user should see the following inputs in this file:

```
*BRACE CHORD PUNCH D   T   d   t   GAP FYLD THETAT TW SWAP
31 11 3 39.370 1.575 29.528 1.181 0.00 36.0 0.0 0.00 0
32 16 3 39.370 1.575 29.528 1.181 0.00 36.0 0.0 0.00 0
33 21 3 35.433 1.181 29.528 1.181 0.00 36.0 0.0 0.00 0
34 6 3 39.370 1.575 29.528 1.181 0.00 36.0 0.0 0.00 0
35 25 3 35.433 1.181 29.528 1.181 0.00 36.0 0.0 0.00 0
36 24 3 35.433 1.181 29.528 1.181 0.00 36.0 0.0 0.00 0
```

**Step 2:** The user has to open the STAAD.pro editor and change the LEG parameter to 2.0 (i.e. replace the LEG 1.0 command in the input file to LEG 2.0) and re-analyze the STAAD.pro input file. STAAD.pro will read the commands in the "APRUN" file and perform the punching shear checks as per API. Please see the output file to see the details of the API punching shear check calculations.

**STAAD.Pro API PUNCHING SHEAR CHECK TO 20th edition.**

```
-----------------------------------------------
JOINT =     13, BRACE =     31, CHORD =     11
-----------------------------------------------
DIA.  THK.  TYP  GAP  THETA  TAU   BETA  GAMMA Fy   Inc  AISC
Vpa
CHORD  1000.0  40.0 TY   0.0  58.19 0.750 0.750 12.498 248. 1.00  99.
BRACE   750.0  30.0
PASS     API Eqn. 4.1-1 with Ratio =     0.61

CHORD (kN & M)  BRACE (N/mm2)  Vp  Qf  Qq  Vpa  UTIL  LOAD (N/mm2)  Bend Total CASE
Axial:   -4764.   2434.  22.9  0.974  1.367  44.0
IPB:       41.    72.   3.9  0.960  4.613 146.6  0.01  0.57    1
OPB:       55.   105.   5.7  0.981  2.413  78.4  PASS
Axial:    784.    -488.  -4.6  1.000  1.367  45.2
IPB:        3.    24.   1.3  1.000  4.613 152.7  0.00  0.11    2
OPB:        8.    21.   1.2  1.000  2.413  79.9  PASS
Axial:   2544.   -1422. -13.3  1.000  1.367  45.2
IPB:       26.   150.   2.7  1.000  4.613 152.7  0.00  0.33    3
OPB:       36.   196.   4.1  1.000  2.413  79.9  PASS
Axial:   -4022.    1438.  13.5  0.981  1.367  44.4
IPB:       40.    63.   3.4  0.972  4.613 148.4  0.01  0.37    4
OPB:       53.   138.   7.5  0.987  2.413  78.8  PASS
Axial:     830.   -308.  -2.9  1.000  1.367  45.2
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