SACS를 이용한 지진해석

Earthquake Analysis Using SACS

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This design report contains a earthquake analysis and design of BCP-B jacket and deck structure of the booster compressor platform in south bassein field of India. Earthquake analysis will be performed following the provision given in 'API-RP-2A' using 'response spectrum analysis' method. The response spectrum data for the analysis is based on the guideline for zone-iv earthquake area as given in Indian standard -- IS 1893-1984'. The importance factor will be taken as 2.0, and the first ten (10) modes will be superposed to provide design response characteristics. The computer programs 'Dynpac' and 'Dynamic Response' of SACS system developed by 'EDI' will be used for the eigenvalue analysis and response spectrum analysis respectively. Since the dynamic analysis in the 'SACS' system is based on superposition of uncoupled mode shapes which are not valid for non-linear system. The non-linear pile-soil combination is simulated as an equivalent stub pile obtained from the results of 'PILE' analysis with the same gravity load. The steps in earthquake analysis included hereinafter are briefly summarized as below.

1. Introduction

This design report contains a earthquake analysis and design of BCP-B jacket and deck structure of the booster compressor platform in south bassein field of India.

The booster compressor platform, BCP-B consists of eight (8) skirt pile template jacket structure with battered legs supporting deck structure without main pile, which shall be designed to support one building module, three (3) booster compressor modules on main deck [el. (+) 26,400], and other process equipment on cellar deck [el. (+) 18,400]. Also, this platform shall be

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designed to support one crane to handle all equipment and three (3) bridges connected to the BLQ-2, BCP platform and future platform respectively.

Earthquake analysis will be performed following the provision given in 'API-RP-2A' using 'Response Spectrum analysis' method. The response spectrum data for the analysis is based on the guideline for zone-iv earthquake area as given in 'Indian standard -- IS 1893-1984'. The importance factor will be taken as 2.0, and the first ten (10) modes will be superposed to provide design response characteristics.

The computer programs 'Dynpac' and 'Dynamic Response' of SACS system developed by 'EDI' will be used for the eigenvalue analysis and response spectrum analysis respectively.

Since the dynamic analysis in the 'SACS' system is based on superposition of uncoupled mode shapes which are not valid for non-linear system. The non-linear pile-soil combination is simulated as an equivalent stub pile obtained from the results of 'PILE' analysis with the same gravity load.

The steps in earthquake analysis included hereinafter are briefly summarized as below.

1) Select a response spectrum that characterizes the excitation of ground motion.
2) Perform "PSI" analysis to obtain max. Pile head displacement, rotation, and axial force with operating average wave data (h=6.477m) for operating gravity load case.
3) Perform the single pile analysis to calculate an equivalent stub pile with pile head displacement, rotation, and axial force. And, simulate stub pile and pile section modulus. ('PILE' of SACS)
4) Perform the eigenvalue analysis to determine the natural frequency and associated mode shapes of the structural modes. ('Dynpac' of SACS)
5) Calculate the participation factors which indicates the extent to which each mode can contribute to structural response. ('Dynamic Response' of SACS)
6) Determine the modal response for each structural mode by multiplying the amplitude of the response spectrum by the participation factor for each mode. ('Dynamic Response' of SACS)
7) Combine modal response for each mode to obtain the total modal response. ('Combine' of SACS-CQC for modal combination, & SRSS for directional combination)
8) Perform static structural analysis applying normal operating gravity load with simulated stub pile. ('SACS-IV' of SACS)
9) The member forces due to earthquake induced loading are combined with those due to static gravity load. ('Combine' of SACS)
10) Perform the code check in member stresses and joint punching shear stresses. ('POST' and 'JCAN' of SACS.

The computer program flow chart for earthquake analysis is shown as next page. The integrity and consistency of structure will be kept during the analysis and the pertinent design data and calculations are included in the following sections.

2. SACS Program Flowcharts

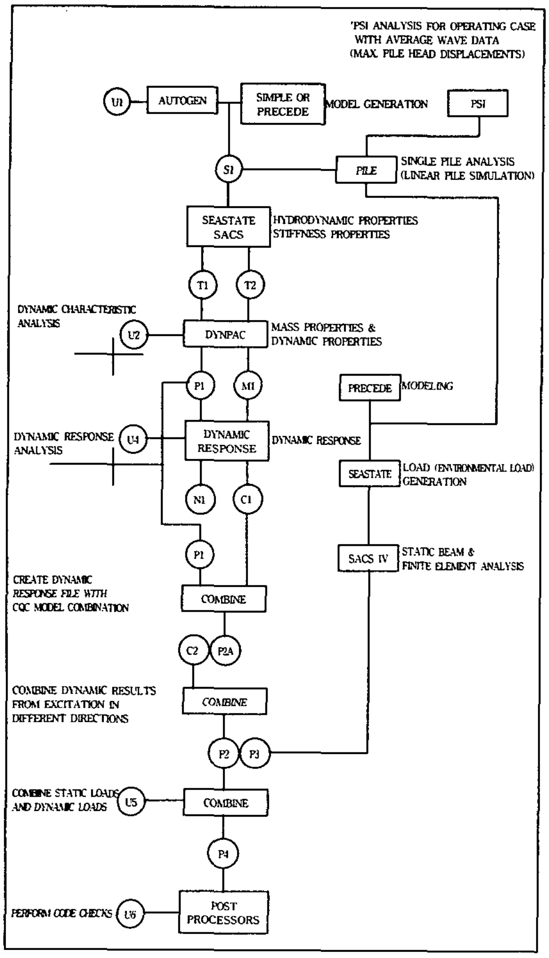

Fig. 1 Earthquake analysis flow chart

3. Design Criteria

Design Criteria

1) The earthquake analysis shall be performed using the response spectrum procedure.
2) The response spectra : figure 2 of Indian standard IS : 1893-1984 shall be used.
3) Factors

$$\alpha_a = \beta I F_0 x \frac{S_a}{g}$$

= Ratio of effective horizontal ground acceleration to gravitational acceleration

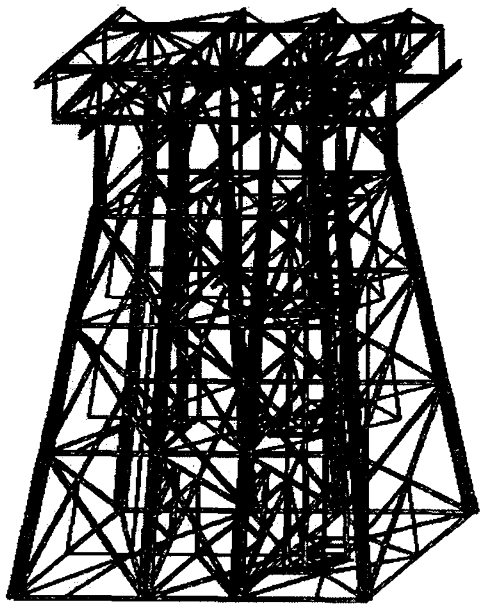

Fig. 2 Overall view for jacket

β = Coefficient of soil-foundation system=1.2
I = Importance factor=2.0
F_0 = Seismic zone factor=0.25(zone-iv)

$$\frac{S_a}{g} = \frac{Spectral\ Acceleration}{Effective\ Ground\ Acceleration}$$

= Average acceleration coefficient

α = β/F_0=Ratio of effective horizontal ground acceleration to gravitational acceleration
= $1.2 \times 2.0 \times 0.25$
= 0.60

4) A response spectrum will be applied equally along both principal orthogonal horizontal axes of the structure. An acceleration spectrum of one-half that should be applied in the vertical direction. All three spectra should be applied simultaneously and the responses will be combined as given in item 5).
5) The complete quadratic combination (CQC) will be used for combining modal responses and the square root of the sum of the

squares (SRSS) will be used for combining the directional responses.

6) In computing the dynamic characteristics of the structure, uniform modal damping ratio of 5% of critical will be used. (Including hydrodynamic effects)
7) The basic AISC & API allowable stresses will be increased by 70%.

Load Cases for jacket analysis

1) Extreme storm wind, wave & current
2) Operating storm wind, wave & current
3) Structural dead loads & buoyancy
4) Equipment & piping dead weight
5) Equipment & piping operating contents weight
6) Open deck area live load
7) Uniformly distributed area live load
8) Deck grated areas excluding wellhead grated area
9) Loading / Unloading area of deck
10) Crane dead load
11) Crane operating loads
12) Elastic bending forces due to curved conductors
13) Reaction from bridge excluding walkway live loads
14) Riser dead loads
15) Reaction from modules
16) Earthquake loading

Applied codes and standards for jacket design

The platform shall be designed in accordance with the following structural design guidelines and the latest codes.

1) AISC : Specification for the design, fabrication and erection of structural steel for buildings.
2) API-RP-2A : Planning, designing, and constructing fixed offshore platforms.
3) AWS D 1.1 : Structural welding code.
4) API-SPEC-2C : Offshore cranes.
5) API-SPEC-2H : Carbon manganese steel plate for offshore platform tubular joints.
6) IS 1893 : Criteria for earthquake resistant design of structure.
7) IS 2062 : Steel for general structural purposes.

4. Mass Simulation

The mass, virtual mass (Added mass), and enclosed water mass for coded members are generated automatically by 'Dynpac' module of sacs program. A 3% weight allowance to account for mill tolerance and weld metal shall be applied for weight generation. In addition of mill tolerance and weld metal, 5% & 10% weight allowance are applied for substructure (jacket) and superstructure (deck) to reflect the relative load contingency, respectively (use group card in the SACS model). The masses of following items, which are not coded structural members, are input as applied loads.

- Jacket appurtenance loads
- Buoyancy loads for submerged jacket appurtenance
- Gravity loads applied on deck structure

The effect of marine fouling on fluid added mass will be considered by 'SEASTATE' module of sacs program, which updates the member cards to account for the density and effective diameter due to marine growth specified on 'MGROV' cards in the sacs model. For computation of fluid added mass, the water surface level has been taken as 2.012m above chart datum in consideration of tidal variation.

- Still water depth for earthquake analysis 60.7+lat (-0.183)+50% of astronomical tide (+4.39/2)=62.712m
- Total applied gravity load for the mass conversion

251.91+48.62+17.05+25.78+15.06+54.92+5961.92=6375.26ton-refer to the eigenvalue analysis output

1) Mass simulation of jacket appurtenance

The gravity loads applied on the jacket inplace analysis will be converted to the corresponding joint mass automatically by "Dynpac" module of "SACS" program. For the detail loading applications, refer to the inplace analysis design report.

- Summary of applied joint mass
  Boat landing/Barge bumper :
  modelled in jacket structure
  Intermediate landing area :
  inputted in deck structure
  F.W pump casing/Sump caisson :
  modelled in jacket structure

Table 1 Mass simulation of jacket appurtenace

	Wx(ton)	Wy(ton)	Wz(ton)
Anode	82.78	82.78	82.78
Launch runner	20.65	20.65	20.65
Walkway	17.50	17.50	17.50
Adjustable stair	2.475	2.475	2.475
Upending padeye	2.00	2.00	2.00
Grout seal, diaphragm & Leg closure plate	20.697	20.697	20.697
Skirt pile guide	33.50	33.50	33.50
Mudmat	55.264	55.264	55.264
Boat landing misc.	3.65	3.65	3.65
Future riser	14.394	14.394	14.394
Total	252.91	252.91	252.91

2) Mass simulation of deck gravity load

The applied loads on deck structure for the jacket inplace analysis have been converted to structural joint mass automatically. For detail load calculation and load distribution, refer to jacket inplace design report. Refer to the input data in section 4.1 input list for eigenvalue analysis.

Table 2 Mass simulation of deck gravity load

Deck appurtenance	64.13 ton
Deck floor beam & plate	105.86 ton
	169.99 ton
Operating load on main deck applied 120 % with contigency	
building weight	797.30 ton
equipments load	2460.00 ton
cable tray load	108.00 ton
Piping load	181.90 ton
Crane	29.50 ton
	3576.70 ton
Operating load on cellar deck applied 120 % with contigency	
Equipments load	442.41 ton
cable tray load	84.02 ton
Piping load	331.96 ton
	858.39 ton
Bridge load on cellar deck	305.66 ton
Open area live load on cellar deck (500 kg/m2 - applied 50 % of open area live load)	200.17 ton
Live load on loading / unloading area (1500 kg/m2 - applied 60 % of live load on loading / unloading area)	106.80 ton
Total	**5961.92 ton with factor**

3) Configuration of building and booster compressor modules

Some dummy frames have been modeled to simulate the stiffness of building and booster compressor modules on the main deck and module's gravity loads have been applied on that joint. However, since the c.g of equipment are not available, the elevation of cellar deck have been modified from el(+)17.594 to el(+) 18.400 to configure the equipment frame's motion instead of modeling the equivalent dummy frames. The modeled dummy frames and load application for the building and booster compressor module are as follows.

Table 3 Configuration of building and booster compressor modules

Building module's c.g (Based on the weight control report)	= el (+) 31.87
Booster compressor module's c.g (Based on the roof of module, conservatively)	= el (+) 36.93

5. Equivalent Pile Stub Generation

It is often desirable or necessary to replace the non-linear pile-soil system with an approximately equivalent linear member. Static analysis of the linearized system for instance, may be sufficiently accurate. For the dynamic analysis, it is necessary to linearize the foundation. The equivalent pile stub have been generated as following steps.

1) Static "PSI" analysis have been performed to obtain the max. Pile head displacement, rotation, and axial pile force with operating gravity load used in the jacket inplace analysis for the operating average wave data.
2) "PILE" analysis has been performed to calculate an equivalent stub pile with pile head displacement, rotation, and axial force.
3) The generated equivalent pile stub length and pile section modulus will be input as dummy pile in eigenvalue analysis model.

The soil data for BCP-B p/f is extracted from "Final report on soil investigation" of "IEOT" which has developed and recommended axial capacity and axial / lateral load-deflection('t-z', 'q-z', & 'p-δ') curves for 137.2(cm) diameter pile. And these values have been adapted for 167.6 (cm) diameter pile and inputted as soil data for 'pile' analysis. Also, these soil data are stretched with soil modifier due to pile group effects as done in inplace analysis. The converted soil data stretched with pile group effects (modifier 3.0 for lateral dir., 2.8 for axial) are shown on 'PSI' and 'PILE' input soil data.