# VIBRATION MEASUREMENT IN OFFSHORE STRUCTURES

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*Paper No. 1667. (quote when citing this article)*
Eleventh World Conference on Earthquake Engineering
ISBN: 0 08 042822 3

## ABSTRACT

This paper shows a review of the methodology used at Instituto Mexicano del Petroleo to deal with dynamic problems associated with vibrations induced by ambient and machinery excitation in Offshore Structures, describing recent works developed for PEMEX in some platforms located in the Campeche Bay.

Emphasis is made in two special projects: one related to the vibration measurements in offshore installations for certification purposes, and another dealing with measurements of the dynamic behavior in the time domain (because different ambient excitation and changes in the mass located on the decks or variations in the stiffness for some parts of the structure).

Finally, the efforts done for PEMEX to identify the dynamic behavior of offshore structures in the Gulf of Mexico due to seismic excitation, trough the installation of a Seismic and Accelerographic System for the Campeche Bay, where some offshore platforms will be instrumented and seismic stations will be located at the continental shelf.

## KEYWORDS:

Vibration Measurement, Seismic Instrumentation, Offshore Structures, Jacket Structures, Sonda de Campeche, Instituto Mexicano del Petroleo.

## A BRIEF REVIEW OF OFFSHORE PLATFORMS:

In Mexico, most of the oil and gas exploitation is performed in the marine fields at the *Sonda de Campeche*, which is located in the south part of the Gulf of Mexico, 80 kilometers offshore Campeche, in water depths ranging from 15 to 80 meters. The structures required for supporting the equipment and personnel necessary to make possible these activities have to satisfy certain conditions to withstand all the loads which may occur during their life. Each platform is constructed in structural steel for its three main parts:

The deck(s) in the upper portion of the structure, provide area and support necessary for all the equipment and accessories needed for the exploitation, it is supported for tubular columns (three, four, six, eight or twelve) which are welded to the piles in the working point. The jacket is the submerged part of the structure, and is made of tubular columns (called legs, which number equals the number of columns in the upper part) and tubular braces which provide lateral stiffness. The jacket is welded to the piles in its upper section ("working point"). The piles are tubular members which pass through the legs to penetrate into the sea bed to reach the design penetration.

Offshore platforms are subject to different kinds of excitation, but in this case, we only will make reference to that of dynamic nature. That is the case of the forces due to waves, currents, wind and earthquakes which produces dynamic excitation in the whole structure and, may be the forces governing the design. There are other kind of excitation considering as local, such the dynamic excitation due to the vibrating machines located on the decks, or the oil passing trough the pipelines which are supported by the upper structure at different points.

It is important to distinguish between two aspects related to vibration monitoring: structural integrity of the platforms and health hazard and comfort to the people working on them.

## VIBRATION MEASUREMENT TO PREVENT HEALTH HAZARD

Due to the great importance given for PEMEX to prevent health hazard to the people working in the offshore installations, an important project was carried out intended to measure the level of vibration in some offshore platforms identifying its effects in the human behavior, and, if necessary, limiting it to prevent health hazard to the personnel, as well as maintain the proficiency of them when performing a specific task and assure a comfortable place when sleeping or resting in accommodation areas.

The basis for the limit used in this study was the acceptability criteria of exposure of human vibration given in reference 2, considering a 12-hours working day for general areas. This criteria establishes the vibration limits divided into five different categories ranging from accommodation areas to that categorized as prohibited in any situation. Table 1 reproduces this information for both horizontal and vertical vibration limits and figures 1 and 2 show the plotted limits for each case.

Equipment used:
-Spectral Analyzer, Hewlett Packard, mod. 3582A, with the following characteristics:

| | |
|---|---|
| Frequency Range: | 0.02 Hz to 25 KHz |
| Amplitude Range: | 3 mV to 30 V |
| Display Range: | 80 dB (Dynamic Range > 70 dB) |
| Display: | Two channel input and capability of displaying or storing two traces simultaneously. The traces may contain: phase, either or both channels, amplitude, either or both channels, phase transfer function, amplitude transfer function, coherence, time function: (either channel can be displayed but not stored, |
| Averaging: | RMS and Time averaging functions and selectable averaging cycles (also there is a Peak hold mode). |
| Filter: | Three selectable filter (PASSBAND) shapes: Flat Topped, Hanning and Uniform. |

Specifications for Endevco 5241 vibration sensor:

| | |
|---|---|
| Dynamic Range | 10 g rms to 30 Vdc |
| Sensitivity (at 100 Hz) | 750 mV/g with 30 Vdc excitation |
| Frequency Response | ±10%, 0.2 to 2000 Hz (sinusoidal) |
| Voltage Requirement | 30 Vdc |

**Procedure:**

It was taken records from discrete points over the main decks of the platforms, making a grid with crossing points equally separated mainly around the vibrating machinery and pipeline supports and in the normal access for personnel for transit and maintenance of equipment, control rooms and living rooms, for the platform decks monitored. This was done over the plate, grating and structural elements where possible. For the living platform, we gotten additional records inside the living rooms as well as in the floor and roof of the module and the helideck.

**Vibration measurements**

The acceleration sensors sent the analogic signal to the spectral analyzer, which processed this input via Fourier Analysis, using a display from 0 to 100 Hz and a Flat Top passband shape with four averaged rms samples. The spectral acceleration amplitudes were taken and reported in the graphics for horizontal and vertical vibration recommended in ref. 4, two of them are reproduced in figures 2 and 3.

**Conclusions and Recommendations**

From the results gotten from the vibration monitoring performing in a set of offshore platforms, we concluded that in most of the areas the vibration levels are below the limits recommended for avoiding health hazard to personnel or lost of proficiency in performing their work. Specific points in some platforms show vibration levels exceeding the mentioned limited, they were identified and locally reinforced when necessary, another points reported high vibration levels when operating some special equipment, as fire stations. Some equipment showed excessive vibration, and recommendations were given to repair it or to use some isolation system, as required.

## MONITORING THE OVERALL BEHAVIOR OF AN OFFSHORE STRUCTURE

Some structures have reported significant movements when important changes in structural components or mass density are performed. In this cases, a monitoring period of the movement characteristics is performed and the results have to be interpreted and, when possible, compared with previous measurements done in the same platform. In this case, both analysis in the time and frequency domain are used to establish the integrity of the structure or the possible stiffness reduction.

**Equipment**

Additionally to the equipment described in the previous section, we used a set of triaxial accelerometers which may be interconnected to work simultaneously with automatic trigger through predetermined acceleration level and storage in solid state. A personal computer (Lap Top) is necessary to handle the sensors and to perform some "in situ" analysis.

**Procedure**

Previously to the monitoring period, the system has to be modeled and analyzed using the data provided by the client. The models are handled to try to reproduce the phenomenon reported, and implement possible solutions. Next, the vibration monitoring period is performed, using different techniques:

1.- Triaxial interconnected sensors are located in different points of the decks, recording simultaneous vibration for each location. With these data, it is possible to detect the main dynamic characteristics of the whole platform, which are compared with the data gotten from previous analysis.

2.- Uniaxial sensors are used to monitor the behavior of two discrete points in very specific places and directions. From these data, it is possible to review the vibration transmission between differents levels, identify the transfer function or torsional movement in the platform.

All the data collected are used to calibrate the analytical model, review the implemented solutions and conclude the final results.

### Conclusions

To monitor the structural behavior of offshore platforms, has permitted to assess the structural integrity of them and to prevent future problems associated with dynamic response.

## IMPROVED THE SEISMIC ASSESSMENT USING SEISMIC ACTIVITY AND RESPONSE MONITORING

### Seismic Assessment

The factor governing the design of offshore structures in the Campeche Bay traditionally has been the effect of the wave forces. The seismic forces have not been mandatory for the structures designed until recent years, when the exploitation had to be done in deeper water and the platforms became more flexibles. The nature of our country makes a potentially seismic zone everywhere, and de Campeche Bay is not the exception.

Some Seismic Risk studies have been carried out, from which we gotten different design spectra for the *Sonda de Campeche* (fig. 4). Unfortunately, all of them are based in seismic information gotten for places located far away from the place of interest, because we do not have any instrumented site near the platforms zone.

It has been a matter of discussion in PEMEX the applicability of the spectra gotten in this way, and efforts has been made to instrument some places around the Sonda de Campeche to monitor the seismic activity, as well as some platforms to review their structural behavior.

The Instituto Sismologico Nacional, from the Universidad Nacional Autonoma de Mexico, installed a extensive system covering the most important seismic zones in our country, but the coast of the Gulf of Mexico is still uncovered for this system, expecting doing it in a very short time.

Both goals were joined and, in a very close date, a seismological system will be installed around the Campeche Bay with the objective of monitoring the seismic activity, and will be complemented with a set of instrumented platforms for monitoring the structural response of them, as seen in figure 5. Instituto Mexicano del Petroleo has the task of providing the technical support required for the implementation of this system in the offshore installations owned by PEMEX.

This system will give us enough information to validate the results gotten from extrapolation of data from other places, letting us to confirm or to modify the design spectra used in the seismic assessment for the offshore platforms. We will be able to validate our mathematics models used in the analysis of dynamic behavior of offshore structures.

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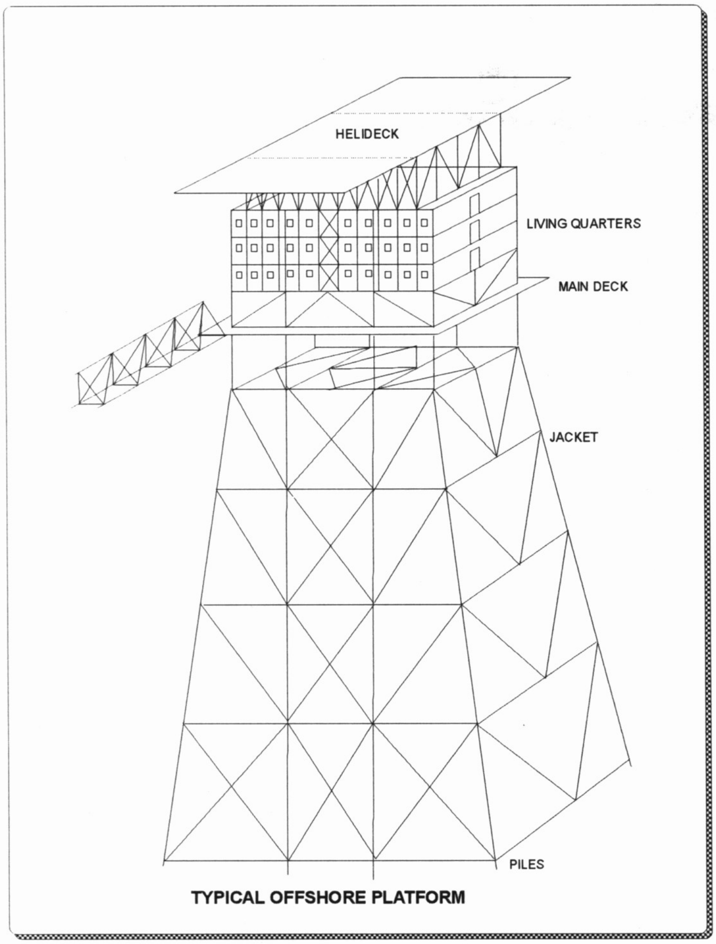


FIGURE 1.- A TYPICAL OFFSHORE STRUCTURE.

| CATEGORY | DESCRIPTION |
|---|---|
| I | RESTRICTED AREA (LESS THAN 4 MINUTES EXPOSURE) VIBRATION LIMITS. |
| II | JUST ACCEPTABLE LOCALLY TO EQUIPMENT. |
| III | RECOMMENDED DESIGN VIBRATION LIMITS FOR ALL GENERAL WORK AREAS. |
| IV | RECOMMENDED DESIGN VIBRATION LIMITS FOR OFFICE AND CONTROL ROOMS. |
| V | RECOMMENDED DESIGN VIBRATION LIMITS FOR SLEEPING, RECREATION AND SIMILAR AREAS IN LIVING ACCOMMODATION. |

TABLE 1.- DESCRIPTION OF VIBRATION LIMIT CATEGORIES FOR OFFSHORE INSTALLATIONS

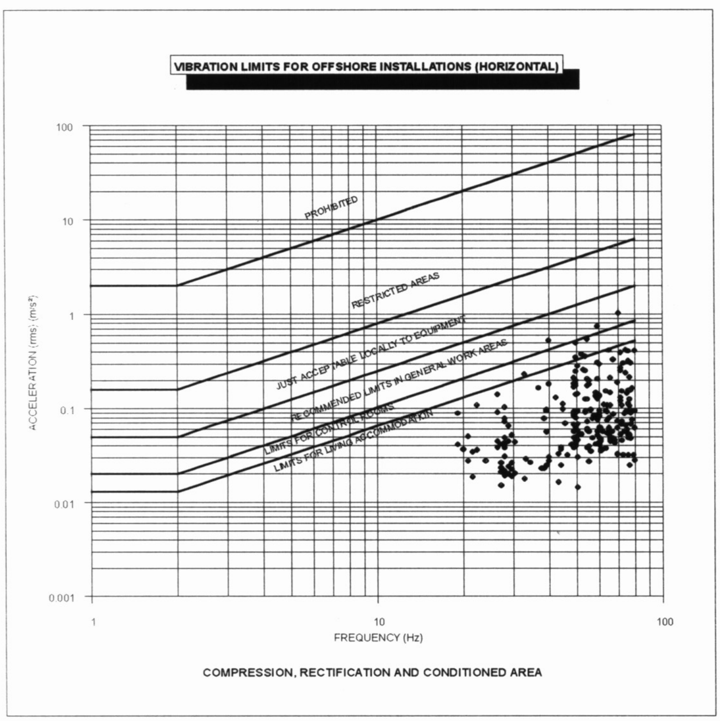


FIGURE 2.- VIBRATION LIMITS FOR OFFSHORE INSTALLATIONS: (HORIZONTAL AXES) AND SOME ACCELERATIONS LEVELS REGISTERED.

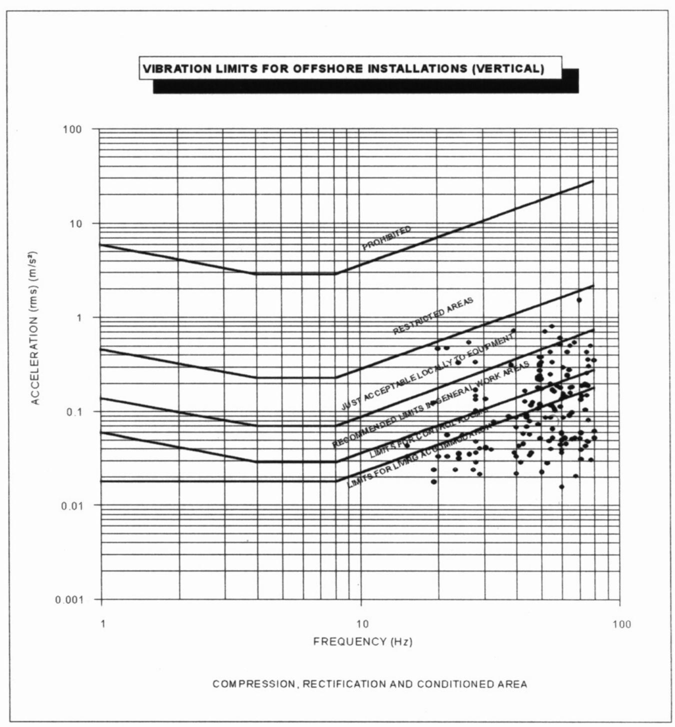


FIGURE 3.- VIBRATIONS LIMITS FOR OFFSHORE INSTALLATIONS (VERTICAL AXIS) AND SOME ACCELERATIONS LEVELS REGISTERED.

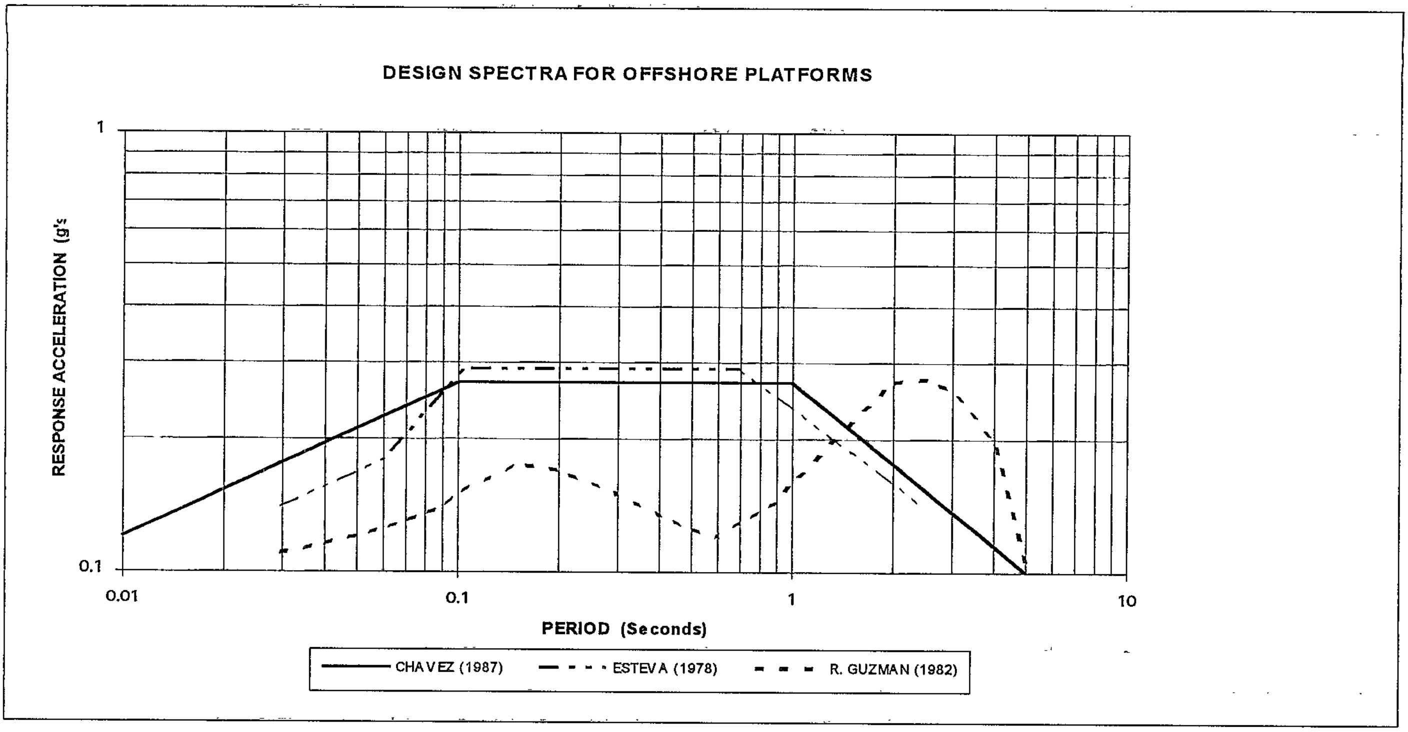


FIGURE 4.- SOME DESIGN SPECTRA FOR OFFSHORE PLATFORMS

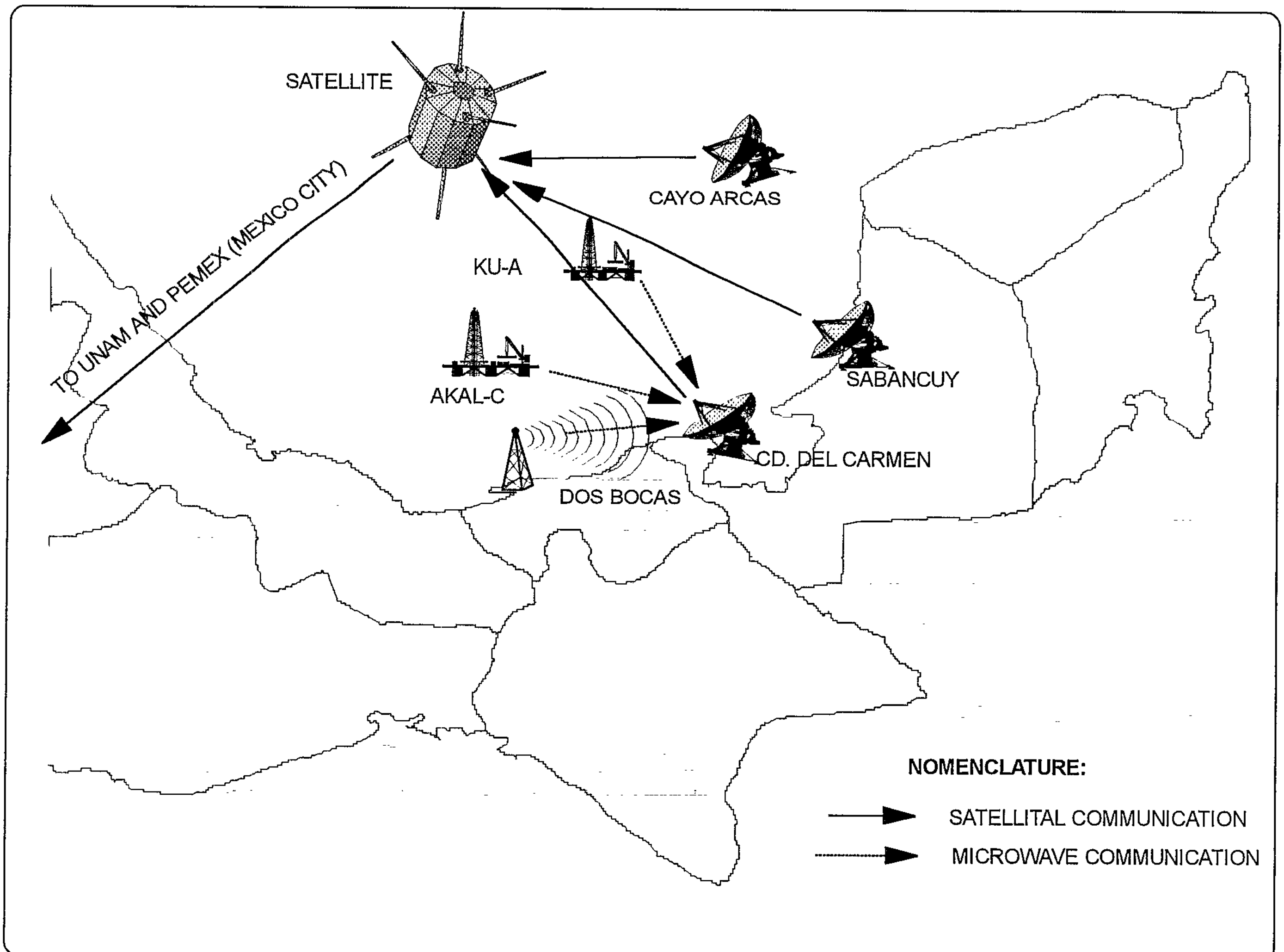


FIGURE 5.- LOCATION OF SEISMIC AND ACCELEROGRAPHIC STATIONS IN THE CAMPECHE BAY.