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PROPOSAL OF A SERVICEABILITY CRITERION FOR OFFSHORE PLATFORMS IN THE BAY OF CAMPECHE

Ramsés MACÍAS JIMÉNEZ[1] and Joel A. GARCÍA VARGAS [2]

SUMMARY

A serviceability criterion according to the results of the vibration evaluation levels in offshore platforms located in the Bay of Campeche, based on a vibration monitoring, is presented. For this task, accelerometers were installed in specific points in order to obtain basic data of their behavior. The total response of the structures was computed using the root-mean-square acceleration. According to the vibration limit levels obtained, we do not only know if these platforms are within the recommended international standard but also if they have to be requalified, which allows the best decisions on repairing and inspection intervention be taken.

INTRODUCTION

Structural integrity of offshore platforms is a special concern to determine, because of the environment characteristics, as well as the difficulty that we have in evaluating the evolution of their dynamics properties along their service life. Thus, they have to be designed or evaluated according to codes and standards that include these local characteristics and the appropriate conditions of each country.

As a part of the structural evaluation one of the current methods used in inspection is the vibration monitoring, which is possible to determine the global behavior of the offshore platforms due to environmental and accidental conditions such as seismic movements through measurement recording. As several authors have discussed: Freitas[1], Tallin [2], Ellinwood [3], the action to which are exposed the platforms are important sources of dynamic excitation and the result of this dynamic movement may become distinctly, perceptible and even objectionable to the occupants. The vibration outside these limits of tolerance may characterize a serviceability limit state.

Regarding these demands, this work presents the vibration monitoring analysis through structural instrumentation. The platforms were monitored and their dynamic characteristics were identified in order to locate excessive displacements and accelerations. With this information has been possible to establish a serviceability criterion for these offshore structures monitored and note where should have considered an eventual reevaluation. Further, this technique may be applicable to other platforms.

[1] Graduate Student, Mexican Petroleum Institute, Mexico.
[2] Ph.D. Research Civil Engineer, Mexican Petroleum Institute, Mexico. Email: jgarciav@imp.mx

EVALUATION OF VIBRATION WITH RESPECT TO EFFECTS ON HUMAN BODY

It is well known how structural vibration may cause annoying, discomfort, damage and destruction. Human body is a good sensor to vibration, which may conduct to fatigue and consequently working decrement, irritability, work accidents and even dead.

Tallin [2], among others [3,4,5], discuss that sensitivity and tolerance of human body towards vibrations depends on direction and kind of vibration applied; frequency and duration of exposition; body position, age, physical condition and mental attitude of the person. Human response to vibration may be classified according to objectionable level or discomfort that it produces, which may be subjective and variable from one to one. In this instance there are several scales and criteria to evaluate.

Numerous studies have been conducted in attempts to relate levels of structural motion to human comfort or tolerance levels. Furthermore, studies such as Ellinwood's [3] concerned with human response to structural motion have concluded that acceleration is the best indicator of potential discomfort to occupants; it appears to be the most appropriate response quantity to use as a limiting motion parameter. The acceleration is directly related to the whole-body forces that are sensed kinesthetically and since the vibration persist for extended period of time, as during windstorms, the root-mean-squared (rms) acceleration appears to be a better indicator of objectionable structural motion in the minds of building occupants than isolated peak accelerations.

EVALUATION STANDARDS APPLIED TO OFFSHORE STRUCTURES

Respecting on evaluation standards, each country dealing with this kind of industry generally is being supported by one of them. In this case, ISO Standardization has been the main to consider.

In the case of occupants response evaluation of fixed offshore structures as well as measurement and evaluation of human exposure to whole-body mechanical vibration, the British Standards Institution (BSI) [6,7], presents an equivalent guidance to that of ISO, presented in table 1, which has been made by Technical Committee ISO/TC 108 of the ISO and in the development of which BSI played an active part**.** One of the documents where is possible to find this information is that presented by Bomel [8].

Table 1. Equivalent Standards BSI and ISO

BSI		ISO	
BS 6841	Measurement and evaluation of human exposure to whole-body mechanical vibration and repeated shock	ISO 2631-1	Measurement and evaluation of human exposure to whole-body. Part 1: General requirements
BS 6472	Guide to evaluation of human exposure to vibration in buildings (de 1 a 80 Hz)	ISO 2631-2	Measurement and evaluation of human exposure to whole-body. Part 2: Continuous and shock-induced vibration in buildings
BS 6611	Evaluation of the response of occupants of fixed structures, especially buildings and offshore structures, to low-frequency horizontal motion (0.063 Hz to 1 Hz)	ISO 6897	Evaluation of the response of occupants of fixed structures, especially buildings and offshore structures, to low-frequency horizontal motion (0.063 Hz to 1 Hz)
BS 3015	Vibration and shock - Vocabulary	ISO 2041	Vibration and shock - Vocabulary

At IMP, since this kind of assessment has been performed, BSI Standards have been the most used based on its worldwide-accepted confidence.

VIBRATION MONITORING ON MEXICAN OFFSHORE PLATFORMS

Since two decades before, an inspection and maintenance philosophy for offshore platforms was implemented by PEMEX-IMP [9,10] with the advancing of an abroad company, in which it is established that the marine facilities must be inspected thoroughly each five years with the application of long-term inspection programs. These programs are integrated at the same time by short-term programs. At the end of each short-term program an evaluation of the installation is effected and the results will define, with new conditions detected, some changes to the subsequent inspection programs. Upon detecting conditions that could increase the accepted structural risk, an assessment will be carried out to issue the relevant recommendations.

Based on the previously exposed, it is developed a permanent alertness of the platforms. In this way, the structural integrity of the platform will be guarantee during its in-service life.

In addition to the inspection programs, it is applied a special inspection programs in those cases where is imperious to know the sate of the facilities as soon as possible. After hurricanes, earthquakes, fires, flow outs or any other type of accident that could increase the risk of the platforms. Pérez [11,12] gives a brief description about Bay of Campeche characteristics; moreover, for the facilities located in this region exist a database that contains the information gathered through the accomplished inspections. These data permit to know the current state of each one of the platforms.

As a part of the structural evaluation, one of the methods that are used in inspection is vibration monitoring, which is considered to be the process whereby response characteristics of a structure are measured, either continuously or at regular intervals, by using accelerometers installed on platforms topsides with appropriate data processing and filtering hardware.

Upon the request of PEMEX, a vibration assessment was conducted on four offshore platforms located in the Bay of Campeche. Platforms dynamics characteristics were identified by means of records obtained throughout a monitoring campaign of displacements and accelerations response on the platforms.

DATA ANALYSIS RECORDED FROM A MONITORING SYSTEM

As above mentioned, four platforms to analyze and to know their dynamic behavior throughout an established period were considered. The monitoring duration changed from one platform to another, due to outside circumstances of this study whereas in this case appropriate for analysis because of given operations that should have performance on the respective structure.

Recording data was carried out according to table 2. As indicated, simultaneous measurement was presented only for gathering and production platforms; otherwise the recording data period of the others was conducted in different periods.

Table 2. Platforms monitored

Type of platform	Period of monitoring (months)
Gathering	4
Production	3
Living quarters	4
Telecommunications	3

Each sensor had a specific position on the platform. As reference, short side (broadside) and long side (end-on) were considered as transversal and longitudinal direction, respectively. In the case of telecommunication platform the connecting bridge was the one corresponding to longitudinal direction.

Every analysis had typical characteristics due to different factors, among all: type of service of each platform, natural phenomena and different operations occurred during the monitoring campaign. That was the case of one seismic event presented. It could be registered while the monitoring was performed on the first platform monitored, that of gathering service. The most important response for obtained acceleration and displacement response is presented on figures 1 and 2, respectively.

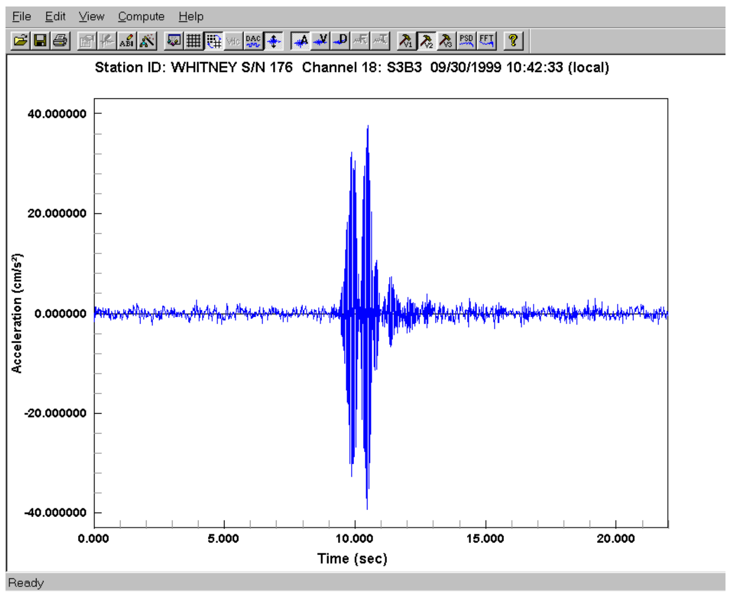

Figure 1. Response for acceleration registered on one sensor located at top level of platform decks from a seismic event.

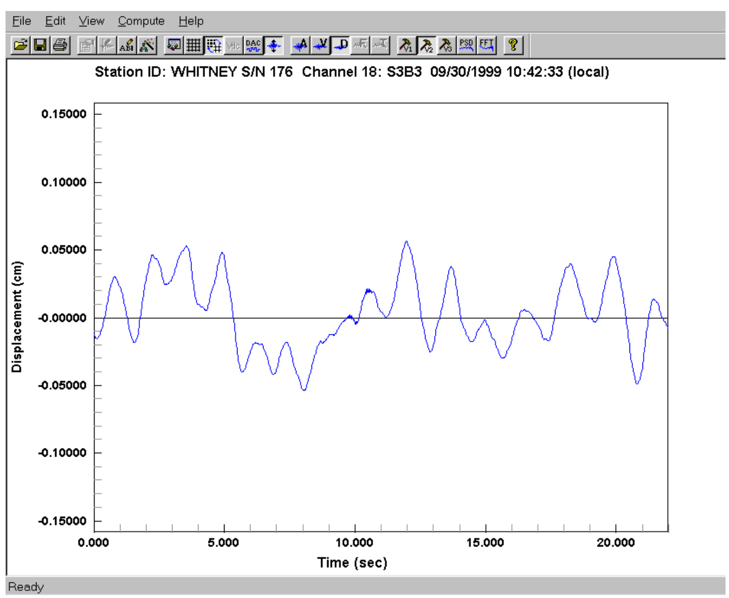

Figure 2. Response for displacement registered on one sensor located at top level of platform decks from a seismic event.

After data recording, a selection of them to optimize the sample was performed. The software allowed accurate data processing, for instance; Fourier amplitude response spectra were generated and the fundamental period and damping percent were estimated.

Otherwise, according to a study performed on 18 offshore platforms located in the Bay of Campeche was founded that the fundamental period was less than 2.2 Hz. A period for a low or high frequency depends on those corresponding gravitational loads and number of legs. That is verified in table 3.

Table 3. Dynamic properties of the platforms monitored

Type of platform	Period (s)	Frequency (Hz)
Gathering	1.7	0.58
Production	1.5	0.66
Living quarters	1.13	0.88
Telecommunication	1.1	0.9

SERVICEABILITY CRITERION

Since objectionable vibrations may characterize a serviceability limit state, one should not have to rely on speculative opinion to determine the adequacy of a given system once it has been designed and constructed.

According to those motions reported in the offshore structures presented, horizontal dynamic motion predominates and, for cases where certain non-routine tasks or skilled operations have to be performed, vibration limits should relate levels of structural motion to human comfort and adequate tolerance levels. For this reason, it is necessary to develop and establish serviceability criteria and design codes to control excessive objectionable vibrations, as well as problems derived from them.

Based on vibration data collected from monitored platforms and with reference to those codes referred, Macías [13] presents a simple serviceability criterion for the case of these offshore platforms.

As mentioned before, the rms acceleration was computed and only the mean of this response along its correspondent frequency for each platform is used and showed in the consequent graphics, according to table 4.

Table 4. Statistical characteristics of recorded data from monitored platforms

Type of service	Horizontal			Vertical		
	μ	σ	COV	μ	σ	COV
Gathering	0.024866	0.001392	0.056005	0.007971	0.005767	0.723445
Production	0.005114	0.001928	0.376991	0.005175	0.002780	0.537227
Living quarters	0.005976	0.002847	0.476439	0.002869	0.002039	0.710733
Telecommunications	0.033701	0.009482	0.281371	0.012129	0.002398	0.197726

In figure 3, suggested satisfactory magnitudes of horizontal motion of offshore fixed structures in curve 1 are presented, whereas curve 2 corresponds to average threshold of perception of horizontal motion by humans. Similarly, figure 4 shows the same curves but for vertical motion (Tables 5, 6).

Table 5. Serviceability criterion for horizontal dynamic motion

Curve	$f \leq 1.0\,Hz$	$1.0Hz \leq f \leq 2.0Hz$	$f \geq 2.0\,Hz$
1	$a \leq 0.156\,f^{-.4133}$	$a = 0.156$	$a \leq 0.0774\,f^{1.0111}$
2	$a \leq 0.0144\,f^{-.4531}$	$a = 0.0144$	$a \leq 0.007\,f^{1.0328}$

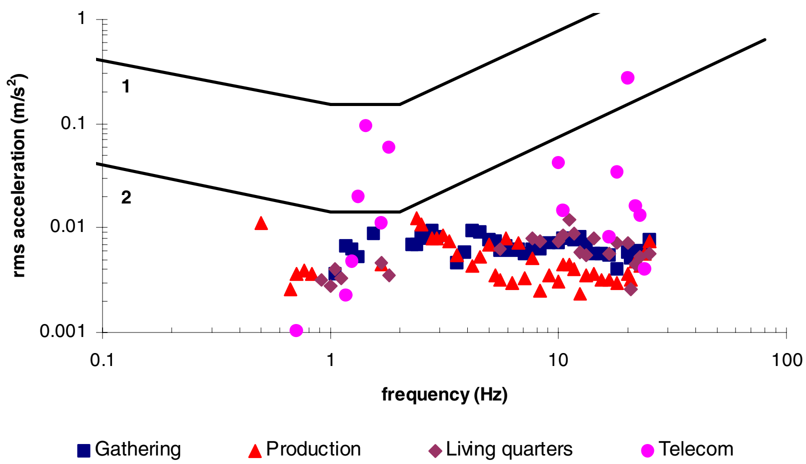

Figure 3. Tolerance levels for horizontal dynamic motion.

For vertical axis, the suggested curves are the following:

Table 6. Serviceability criterion for vertical dynamic motion

Curve	$f \leq 2.0\,Hz$	$2.0Hz \leq f \leq 4.0Hz$	$f \geq 4.0\,Hz$
1	$a \leq 0.48\,f^{-1.0614}$	$a \leq 0.23$	$a \leq 0.0836\,f^{0.7302}$
2	$a = 0.018$	$a = 0.018$	$a \leq 0.0062\,f^{0.7686}$

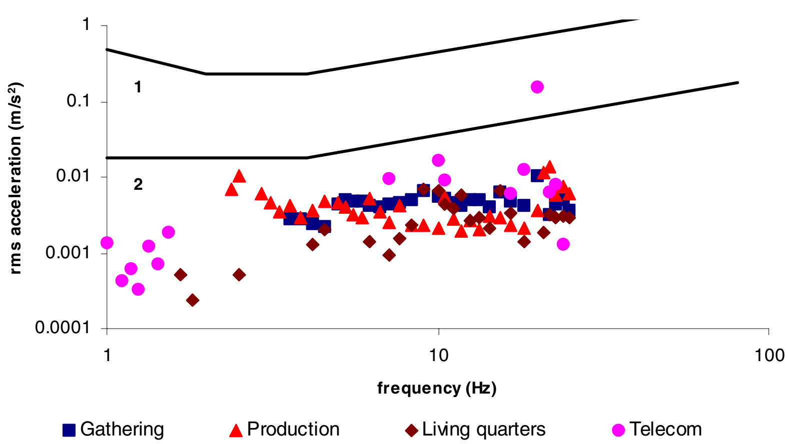

Figure 4. Tolerance levels for vertical dynamic motion.

RESULTS

Structures' behavior was satisfactory respecting on the level of recorded vibrations obtained from sensors located on principal decks for the lapse of monitoring. The obtained displacements correspond to such values that may consider very small.

These results are based on data obtained from the period of monitoring of each structure in-service and included one part of the hurricane and storms winter period corresponding to that regularly affect these structures. In the same period, personal operating on structures did not report any other event as shift hitting against one of the platforms leg or another. The seismic movement recorded when monitoring did not generate a significant response on the gathering platform, whereas on the production platform that movement was not recorded.

It has to be noticed that when some areas were not specifically for living on additional modulus platforms (production, gathering), the related vibration levels would hardly be within those desirable; in spite of those vibration levels might satisfied the other functions or areas of that structures as the case of production platform.

DISCUSSION

The obtained results from analysis of vibration monitoring have shown that on the principal decks of these structures, the levels of vibration are within the established limits for offshore platforms. Nevertheless, to know the real level that can be felt by personal of general working areas, control rooms and living quarters, it would be feasible to carry out a vibration measurement in those areas and to identify how suitable they are within the vibration limit levels for offshore platforms.

This work would enable to complete the information about the global behavior through monitoring of facilities located in the same area and to know the real level of vibrations in specific areas of these facilities.

It would be convenient that in future works of vibration monitoring on offshore platforms would carry out measurements of movement on specific areas such as control rooms, personal areas and zones of technical use or living quarters, which measurements will be less in duration than that corresponds to the analysis of the global behavior of structures. These measurements in certain areas could be performed before or after the global monitoring on the structures.

CONCLUSION

Based on reported past experience and as a part of the inspection and maintenance philosophy for offshore platforms implemented by PEMEX-IMP, the instrumentation of four offshore platforms was carried out. For this task, the vibration monitoring has been a current tool to know the structures' global behavior. By using this method was possible to identify if the obtained vibration levels were within the accepted levels of the referred standards for offshore structures.

As a result of this evaluation through a monitoring campaign on the concerned platforms, a useful simple serviceability criterion was obtained. It provides a reference that notes how simplified rules for the evaluation of the performance of a given offshore structure to an acceptable confident degree can be developed without the need of complex computations.

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