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Adequate Design Criteria: the Key Issue to Attain Project Quality

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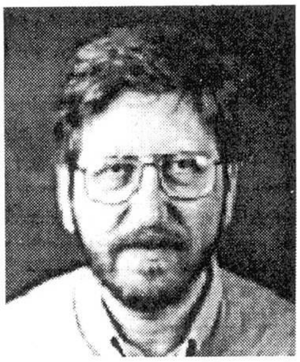

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Abstract

When one speaks about a design criteria to be used to design a structure the first thought to come to one's mind is usually a specific applicable code. In design practice one of the first documents to be prepared in any structural design is usually that called "Design Premises". In it the designer tries to consolidate all the design data and establishes the analyses and verifications that will be performed within the scope of the job. If the object of the project is a common structure, conceived according to well-known existing solutions, this document is really just an expanded description of specific code requirements for that type of structure. When, however, the structure to be designed is based on some new structural concept or has record breaking dimensions, or still when local conditions call for unusual loads, the engineer must stop to ask himself if there is any kind of verification, that must be added. He must consider effects, which sometimes lie beyond the state-of-the-art and that could cause his structure to fail or to fail to meet workability requirements. Some examples of structures listed under these conditions and which have encountered problems are presented below:

- A Shallow Water Fixed Offshore Platform Island

This example deals with the installation of oil production facilities in very shallow waters (approximately 12m), where an artificial island replaced the conventional fixed platform. The chosen concept was to use a crane barge to install a pre-assembled cylinder made of sheet piles, which were already interconnected and held together by a purpose built frame. After being set on bottom the construction sequence was to drive the individual sheet piles, fill the volume inside the cylinder with sand and then secure the whole assembly with a top concrete slab. The actual offshore facilities would then be floated out and installed on “solid ground”.

On paper everything seemed perfect, but as soon as the first assembly was lowered into the water a small swell, no more than 1m high, hit its side and gently bent the first sheet pile inwards. This motion was then repeated by the two adjacent piles and again subsequently by the others forming a type of bending wave around the assembly on both sides. When these two waves met at the diagonally opposite side of the sheet pile cylinder they clashed and sent back two reflective waves in the opposite direction. Again it could be seen as they moved around the cylinder and, once again, they clashed when they met. This time, however, the impact was sufficiently strong to crack the weld that was connecting the first pile to the supporting frame. The sheet piles began to drop, one by one, from the supporting frame bending and twisting in such a way that the crane could no longer proceed to lower the structure onto the seabed nor lift it, bringing it back to the barge deck.

Can any one be blamed for the lack of quality of this project?

- Total Collapse of an Export Terminal on the Amazon River

A second interesting sample accident is one that occurred in 1994 to an ore ship-loading export terminal built in the 50s on the Amazon River. It was destroyed by great wave created by a landslide, which took place on an island in the river over 500m away. This wave threw a ship, which was being loaded, against the terminal. Also in this case one should ask if this accident could have been avoided by a more adequate design criteria.

- Main Span Problems of the Rio - Niteroi Bridge

The Rio - Niteroi Bridge has presented two chronic problems during the last 25 years, since it was built. The first is related to mid span wind vibrations, which in general occur for wind speeds around 65km/h. These cause discomfort to the users, but don't endanger the structure because the corresponding stresses are low. There were, however, two occasions in which it vibrated in a different manner, causing the users to panic. In both cases wind speeds were found to average 120km/h over a longer period. Wind tunnel tests have shown that this vibration took place in a second structural mode. Although these vibrations had been a major concern during the design phase the state of the art calculations had shown they wouldn't be a problem.

The second problem is related to the excessive flexibility of the steel deck cover plating. It was designed adequately for structural purposes, but unfortunately it undergoes deformations due to service loads, which are higher than those that the pavement can withstand. The result of this is that the pavement cracks and is easily destroyed due to water infiltration, which occurs during subsequent rains. This is a typical example in which there was a discipline interface problem, that wasn't adequately addressed by project quality assurance. It therefore, doesn't serve the purpose of this paper.

- The Ipanema Sewage Pipeline

The last example to be addressed here is that of a 2.8m diameter concrete pipeline, built to throw $6m^3$/sec of sewage from the southern part of Rio de Janeiro 4.5km away from the Ipanema beach. Unlike many other similar type constructions, which are laid directly on the seabed, it was built approximately 2m above the bottom, supported by discrete steel open-ended pipe piles spaced every 50m. After twenty years in use, one of these piles broke dropping the pipeline onto the seabed. A new V shaped equilibrium position occurred at the missing support, but fortunately without disconnecting the adjacent pipes, thanks to the flexible design of the concrete head connection at the top of the pile, which absorbed the rotation at that point. Investigations carried out attributed the failure to fatigue of the welds performed on the steel piles caused by cyclic loads on the pipeline. In the mean time several other supports have failed and the entire pipeline with 70 of such supports, must now be strengthened. Although fatigue design wasn't a state of the art requirement when the aforementioned sewage pipeline was designed, it is still worth asking if a more adequate design criteria could have avoided this.

The paper goes on to conclude that uncommon structures or those subject to uncommon loads are not automatically covered by design criteria presented in specific design codes and can only attain project quality if the corresponding design criteria are adequately established. In order to do so both caution and solid engineering judgement exercised by highly experienced engineers are required during the preparation of the "design premises".