Large Ferris wheels are very complex structures that require considerable attention during design and construction.

**DESIGN DETAILS THAT HAVE AN IMPACT ON THE SAFETY OF LARGE STRUCTURES**

**PART 1**

by Enrico Fabbri

It is commonly believed that the design and construction of a Ferris wheel is quite simple. This opinion may be partly true when building a small Ferris wheel, but is absolutely not true when dealing with large wheels. In this article we will examine the important critical points that need to be taken into consideration on large fixed Ferris wheels, i.e., anchored to the ground with concrete foundations.

**FORCES IN PLAY**

Unlike many other attractions, Ferris wheels may be subjected to significant wind and earthquake loads. These external factors are significant due to the large surface area exposed to the wind, and the mass of the rotating structure, as concerns earthquakes. In most cases, the sizing of the structure depends on these factors rather than on the calculation of the structure's fatigue strength during routine operation. A good designer therefore needs to appropriately determine the action of wind and earthquakes and design all the structural details needed to distribute these forces down to the ride's foundations. The image below shows an example of how a force acting at the top creates stress on the entire structure, represented by the various colours. Now try and imagine strong winds or intense earthquake forces acting on the entire rotating structure of a Ferris wheel, pushing against it and all of its components. These forces are then exerted on the main axle and therefore on the masts that support the Ferris wheel.

A customer who purchases a large Ferris wheel naturally expects that it can be used for several decades (around 3), without major maintenance work on the structure. We know that installation costs are quite high and therefore it is fundamental that the design of the structure and the structural calculation are extremely accurate: if, for example, after 10 years major defects are found that require the structure to be dismantled, this would mean economic disaster for the operator.

Consequently, carefully evaluating the manufacturer's construction procedures and the specific experience of the engineering firm that carries out the structure, is a customer specific study that should be carried out by the manufacturer's engineer.

**I DETTAGLI PROGETTUALI CHE INCIDONO SULLA SICUREZZA DI GRANDI STRUTTURE**

**PARTE I**

di Enrico Fabbri

È opinione comune che la progettazione e la costruzione di una ruota panoramica sia assai semplice. Quest'opinione può essere parzialmente vera quando si tratta di costruire una ruota panoramica di piccole dimensioni ma non è assolutamente quando invece si parla di ruote di grandi dimensioni. In quest'articolo vedremo quali sono i punti critici importanti che devono essere considerati nelle ruote panoramiche di grandi dimensioni di tipo fisso, cioè fissate al suolo con fondazioni in cemento.

**LE FORZE IN GIOCO**

Differenemente da molte altre attrazioni, le ruote panoramiche possono essere soggette a sovraccarichi importanti dovuti all'azione del vento e dei terremoti. Questi agenti esterni diventano importanti in virtù della grande superficie esposta al vento e della grande massa della struttura rotante, per quanto riguarda invece l'azione del terremoto. Nella maggior parte dei casi il dimensionamento della struttura dipende da questi fattori e non invece dal calcolo della resistenza a fatica della struttura durante il funzionamento ordinario. Un bravo progettista dovrà quindi calcolare nel modo appropriato l'azione del vento e del terremoto e progettare tutti i dettagli strutturali idonei a distribuire queste forze sino alle fondazioni dell'attrazione.

L'immagine a sinistra illustra un esempio di come una forza agente alla sommità determini uno stress all'intera struttura rappresentato dai vari colori. Provate ad immaginare le forze di vento intenso, o di terremoto, che agiscono sull'intera struttura rotante di una ruota panoramica, spingendo su di essa e su tutte le sue componenti. Queste forze si scaricano quindi sull'asse principale e vanno quindi a gravare su tutte le colonne che sostengono la ruota panoramica.

L'acquisto di una ruota panoramica di grandi dimensioni al solo scopo di farla esplodere, che possa essere utilizzata per più decenni (rosso modulo 3) senza manutenzioni straordinarie alla struttura, rappresenta un'opzione assolutamente non consigliabile. Sappiamo bene che i costi d'installazione sono importanti e quindi è fondamentale che il progetto della struttura e il calcolo strutturale siano molto accurati se, per esempio, dopo 10 anni si fossero presentati disastri che obbligassero allo smontaggio, questo per l'operatore sarebbe un disastro economico. Quindi valutare accuratamente le procedure di costruzione del costruttore e valutare l'esperienza specifica dello studio di ingegneria che...
tural calculations is the first step towards obtaining an attraction that will stand the test of time. In particular, the manufacturer’s designers and the engineering firm that carries out the structural calculations must use advanced software that indicate to reinforce the structure only where necessary and no more, so as to obtain a structure that is both resistant and light, and at the same time streamlined and attractive. If the wheel is installed between very high buildings that can create turbulence and whirlwinds, the action of the wind can be simulated using special software or alternatively models placed in a wind tunnel.

FOUNDATIONS
The foundations are a likewise important element that are often not given due consideration. I have already spoken in a previous article (see G&P February 2016) about the importance of the design of a ride’s foundations, therefore refer to this article for further information. In this case, however, the anchoring of the Ferris wheel’s masts to the concrete foundations is even more important. Usually these are anchored to base plates embedded in the concrete foundations using anchor bolts. The masts are fixed to the top of these plates, which is where the problems start. Some manufacturers weld the masts directly to the plates on site, others use flanges with bolts, and others use adjustable anchor bolts. All of these systems are suitable for achieving the purpose, however specifying that:
* each weld and anchor bolt must always be visible, even after assembling the ride, so as to be able to perform periodical inspections;
* each weld must be flawless and inspected using non-destructive testing;
* a system is needed to level the wheel’s structure and compensate for errors that always occur in the level of the concrete foundations;
* the certifying body that inspects the Ferris wheel must also include certification of the systems used to anchor it to the ground.
Another important aspect is that, during an earthquake, the foundations may move in relation to one another, causing further stress on the structure; the foundations must therefore be suitably joined together.

MASTS
The masts of a Ferris wheel represent a relatively simple part from a constructional point of view; usually they are made from round tubular steel for aesthetic reasons. The larger a wheel, the bigger the diameter the masts need to be, and in some cases need to be especially made to measure. The various components of the masts are bolted together, and here it is worth remembering that it is always preferable to use a large number of small bolts rather than few large ones. The larger a bolt, the harder it is to tighten it to the right torque and therefore also carry out periodical checks.

The accessories that are fastened to the masts are also important, such as the ladders for maintenance and the platforms that are used to access the drive system. These accessories are essential and must be designed taking into account local regulations and not only the general requirements of EN-13814, as this type of structure resembles more a building than a funfair ride. In fact, in some cases emergency lighting, fire-fighting equipment and safety signs for the maintenance operators are required.

The base plates of the large Ferris wheel in New York City during assembly. As can be seen, these are enormous.

The various systems are able to ensure that the masts are connected to the ground, another important aspect is that, during an earthquake, the foundations may move in relation to one another, causing further stress on the structure; the foundations must therefore be suitably joined together.

The base plates of the large Ferris wheel in New York City during assembly. As can be seen, these are enormous.

Le piastre di fondazione della grande ruota panoramica di New York City in fase di montaggio. Come si vede, sono veramente enormi.

Sulla parte alta di queste piastre vengono poi fissate le colonne, e qui inizia uno dei problemi. Alcuni costruttori saldano le colonne direttamente in opera su queste piastre, altri usano delle flange con bulloni ed altri ancora usano dei tiranti provvisti di viti di regolazione. Tutti i sistemi possono essere idonei a raggiungere lo scopo, purché avvenga rettamente e con i requisiti giusti.

* che ogni saldatura e tirante siano sempre visibili anche dopo il montaggio dell’attrazione per poter effettuare controlli periodici;
* che ogni saldatura sia eseguita a regola d’arte e ispezionata con controlli non distruttivi;
* che esista un sistema per livellare la struttura della ruota per compensare gli errori di livello delle fondazioni in cemento (che ci sono sempre);
* che l’ente certificatore che ispeziona la ruota panoramica includa anche la certificazione dei sistemi di ancoraggio della stessa al suolo.

Altro aspetto Importante è che, durante un terremoto, le fondazioni potrebbero spostarsi una relativamente alle altre, determinando degli sforzi considerevoli sulla struttura, occorre quindi
AXLE
The axle is the most important part of a Ferris wheel, as it supports the entire rotating structure. Any major problems involving the axle may mean the ride needs to be dismantled, at a very high cost. In this case too, it is worth remembering the value of a good designer and an excellent engineering firm to achieve the objective of long operating life.

The first decisions concern the system used for the rotation of the wheel. Usually bearings are used, however the larger the wheel the bigger and stronger these need to be. For certain designs, standard bearings may not be readily available, and consequently may need to be specially built, meaning much longer delivery times. Above all when wind or earthquake forces are quite significant, it may be more suitable to use large bushings rather than bearings. These, in fact, offer a larger support surface than bearings. These, in fact, may not be readily available, and consequently may need to be specially built, meaning much longer delivery times.

The shaft structure must be designed taking into account the possibility to easily periodically inspect both the structure and the welding, all the pins, bolts and safety pins. All the shaft’s components need to be designed and calculated considering a lifespan that is longer than that specified by EN-13814 or ISO-17842. enrico@fabbrirides.com

can be an excellent example of this, where the construction process is crucial. Proper inspection and maintenance of all components is needed to ensure the safety of the ride. The use of high-quality materials and a well-planned construction process can help extend the lifespan of the ride.

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