More people are becoming acutely aware of the danger of the potential earthquake along the Nankai Trough (i.e. Tokai earthquake, Tounankai, Nankai earthquake).

Takahama Plant of TOYOTA INDUSTRIES CORPORATION is located in Aichi Prefecture, and they initially planned to conduct a seismic retrofit but switched to seismic vibration control based on KKE’s simulation result.

We interviewed Ikuo Kawashima, Project General Manager and Takayuki Nishitani, Manager of Production Engineering Dept., on why and what led them to make their decision.

"Applying concepts on skyscraper to a factory. Taking an optimal reinforcement solution over a conventional approach with half the construction period."

Ikuo Kawashima, Project General Manager (right), Takayuki Nishitani, Manager (left)
Production Engineering Department, Takahama Plant, TOYOTA INDUSTRIES CORPORATION

Is meeting the required “Is” the only answer for earthquake reinforcement?

Please tell us about the company and the Takahama plant.

We obtain a top-class market share around the world for products such as lift trucks and car air-conditioning compressors. There are 10 plants in Japan, including Takahama plant that specializes in productions of lift trucks.

There are many types of buildings in the plant premises. For our first reinforcement project, we chose a few of factories and laboratories that were built based on the old seismic code.

Regarding prevention measures against earthquakes, each plant and office decides which building should be a priority and takes actions. The discussion for conducting reinforcement for factory A came up in an early stage since it had the largest building area and a high density of workers.

So the construction period of the initial plan was too long?

It wasn’t a realistic prevention plan against a major earthquake, which might hit any day. We asked KKE for its support since it specializes in building structures and seismic solutions, and has run a simulation of seismic retrofit in the past for one of our plants.

KKE simulated how factory A would react towards a major earthquake strike under two different patterns. One was “as-is”, the present condition and another was based on a scenario with seismic retrofit proposed by the general contractor. Both results showed that the building will collapse eventually, but the building with seismic retrofit collapsed faster than the status quo.

Factory A was built on a fairly soft ground. We expected to mitigate seismic vibration by satisfying the value of Is over 0.6, but it turned out to produce a building to vibrate stronger on several shaking patterns.

From these results, we made our final decision by the end of 2014 that we would not introduce seismic retrofit plan for factory A. We requested KKE to continue with the studies and make some proposals for new designs.

KKE proposed a design of seismic control to ensure the safety and security of our employees. Instead of strengthening of the building, it proposed to implement dampers on the walls outside the building to absorb seismic vibration. This

A general construction contractor had first proposed a seismic retrofit?

Yes. The Japanese seismic codes require a building to have a "Is (Seismic Index of Structure) more than 0.6". For buildings that don’t meet the index are considered as "necessary to increase seismic resilience".

At first, we considered satisfying the value of Is. There were, however, questions from the executive managers such as "What’s the difference between 0.55 and 0.6?" and nobody could give a precise explanation to it. We asked the general contractor "If we had a value of Is over 0.6, the building will survive a major earthquake, right?" but they never gave a 100% assurance. Leaving the question up in the air, the seismic retrofit plan for the factories came out in the summer of 2014. The retrofit would take 15 years only for factory A, in total 18 years including other factories and labs. This period and the cost were not something that we have expected.

Is is a standard value of seismic performance which is calculated based on seismic strength, seismic ductility and aged degradation of structures.

It is described that against an earthquake of intensity 6-7, a building with the value of Is more than 0.6 has a lower risk of collapsing or being destroyed in the Act for Promotion of Renovation for Earthquake-Resistant Structures of Buildings, No.184-185. (established by Ministry of Land, Infrastructure, Transport and Tourism, 2005) (Citation for Japanese Seismic Diagnosis Association -Japanese only http://www.taishin-jsda.jp/pls.html)
allows keeping the production line going during the construction, thus saves
time and costing drastically.

The perspective drawing of
3D analysis model of factory A

Building image with seismic dampers

— I heard that countless discussions were made between you and members from KKE.

With no precedent case, we had to take detailed steps. It started from having
discussions on seismic control, making decisions on basic design, detailed
design and then proceeding to the construction work.

We finally decided to adopt the seismic control design at the end of 2015 and
the work started from the beginning of 2016. Compared with the initial retrofit
design, we succeeded to shorten the period by half including the discussion
process and the cost by 50%.

We used simulation as a tool, to understand how buildings would respond to a
major earthquake strike and what measures would be effective to secure safety.
The key is to find the most optimal measure for each structure. I would say
customization is necessary for reinforcement.

Seismic control devices were placed on the external part of a building,
thus people were able to continue their operation as usual.

— You chose seismic control design over Is.

We did. If we focused on satisfying the Is and strengthening the building, we
could say “But we followed the act” even when the building collapsed. What we
wanted to achieve was, however, to find a way that ensures the building from
collapsing.

During the project, an evaluation which a third party conducts for super high-rise
building (“evaluation of seismic capacity”) caught our attention. We approached
Professor Hideki Idota of Nagoya Institute of Technology who is an expert on
structural and seismic safety. We explained our standards and concept for seis-
ic control and got feedback, then reflected to our design.

Our seismic control design was concluded a suitable earthquake measure for
factory A. Even if there were an unexpected damage caused by an earthquake,
at least we would be able to explain why we took the measure and it was super-
vised under a seasoned expert. We are considering reinforcement for other
buildings based on the same standard and concept.

— What do you think of KKE?

KKE members worked with passion. We were taken aback by the new proposal
which was deeply thought through but even caused an overheated discussion
within our team. Everyone was convinced that placing the external dampers
would work, but it turned out that it’s necessary to place one damper inside the
building, near to a wall. Then we found an underground tank close to the wall
and realized that we could not place a damper above it.

This was a pain in the neck, but led us to a new discovery that the time and cost
were better installing some dampers inside the building rather than placing all
dampers outside. We plan to take this approach for our next project if the condi-
tion allows.

— Do you have any expectations or requests for KKE?

I was inspired when I heard its mission was to “create new added-values based
on engineering”. The same thing can be said with us manufacturers: technology
is our strength when we challenge the world. Based on its mission, we wish
KKE for further works and contributions to various business fields.

Interviewed in July 2016