CONSTRUCTING EXCELLENCE
in the built environment

Japan's nuclear construction industry

Report of the UK study tour March 2011

Nuclear Industry Association

CONTENTS

CONSTRUCTING EXCELLENCE in the built environment

ACKNOWLEDGEMENTS

We acknowledge Henry Loo with gratitude for setting up the study tour and making the local arrangements, Peter Haslam and colleagues at the Nuclear Industry Association for their support, and Don Ward and Lord O'Neill of Clackmannan for leading the delegation once in Japan. We thank all the tour delegates who contributed greatly to the mutual learning, Adrian Worker in particular who shared his key learnings for this final report, and Emily Dowling who co-ordinated the tour administration.

Many thanks to our other supporters:

- Interpreters Masako Wouter and Anri Uchino
- British Embassy support from Mr Shimizu
- Euan Low of Mott MacDonald for an excellent background briefing.

We owe a huge debt of thanks to our various hosts, who were most gracious and helpful in ensuring we achieved the objectives of the tour:

- Japan Atomic Industry Forum (JAIF)
- Toshiba Corporation
- IHI Corporation
- Taisei Corporation
- Electric Power Development Co., Ltd. (J Power)
- Tokyo Electric Power Company (TEPCO)
- Japan Nuclear Fuels Ltd (JNFL)
- Shimizu Corporation
- British Embassy in Tokyo
- Overseas Construction Association of Japan, Inc. (OCAJI)
- Building Contractors Society of Japan (BCS).

We also acknowledge the extraordinary events of 11 March 2011, when Japan was hit by a Magnitude 9 earthquake, one of the strongest ever recorded, which was followed by a devastating tsunami. The ensuing toll on lives and Japan's infrastructure was immense. Our thoughts and sympathies go out to the Japanese people and our hosts as they deal with and repair the damage and destruction in the aftermath.

Joe Dowling
Deputy Chief Executive
CWC (UK) Ltd

Don Ward
Chief Executive
Constructing Excellence

1.0 INTRODUCTION AND PURPOSE OF VISIT

The UK is at the forefront of the global nuclear renaissance, with plans for up to 16 GW of new nuclear reactors by 2025. Civil engineering construction activities will form a major part of this newbuild programme, ranging from construction management and design through to the creation of supporting infrastructure.

Construction Excellence and the Nuclear Industry Association (NIA) were able to facilitate access to leading players across the nuclear, construction and wider industry supply chain of the highly successful Japanese nuclear construction industry. This not only enabled the study tour delegation to view and discuss at first hand best practice in design and construction, but has established contacts that could be very helpful in the future. As such we hope that this study tour will set a useful reference and benchmark ahead of the UK nuclear newbuild programme.

This report does not seek to learn any lessons which emerged subsequently as a result of the Fukushima nuclear accident caused by the tsunami of March 11, that is for other experts to do.

1.1 The objectives of the delegation

The delegation was made up of a mixture of UK energy providers, contractors, consultants, and industry bodies. The companies involved were Amec, Balfour Beatty/Vinci, Centrica, DBD, Doosan Babcock, HR Wallingford, Kier, Rider Levett Bucknall, Skanska and Synaps.

The specific objectives of the group expressed ahead of the tour were:

1. Create the opportunity for NIA members and tour delegates to see how the nuclear industry has been developing across the world especially in a country where there have been substantial advances in construction.
2. Obtain a greater understanding of the nuclear industry in Japan.
3. To undertake a comparison between Japan and South Korea construction industries.
4. See industry best practice, construction innovation techniques, culture - how does the Japanese construction industry complete projects whilst complying with cost/time/safety?
5. To understand how interface management is brought into nuclear newbuild.
6. To understand how the supply chain is engaged to ensure true collaborative working.
7. To observe the programme design for construction and commissioning, and see the processes in place for capturing learning.
8. To see how the Japanese utilise lean in their construction methods.
9. To understand how the Japanese deliver efficiently to cost and time on a weekly basis and how risk is managed.
10. To learn lessons and avoid making the same mistakes.
11. Observe how the quality issues are tackled and how 'right first time' 100% of the time is delivered.
12. Find out if specific (continuous improvement) tools are put in use to improve.
13. Continue developing CE links with Building Contractors Society of Japan.

1.2 The study tour members

The tour party with our hosts at the Ohma nuclear power station under construction

Twenty people travelled from the UK for the study tour:

Adrian Worker, Amec
Alex Walsh, Amec
Martin Wenban, Amec
Olivier Colle, Balfour Beatty/Vinci
Jenifer Alam, Balfour Beatty/Vinci
Henry Loo, Constructing Excellence
Don Ward, Constructing Excellence
Terry Murphy, Centrica
Emily Dowling, CWC
Joe Dowling, CWC
Len Jones, DBD
Tony Charlton, Doosan Babcock
Mark Liddiard, HR Wallingford
Chris Hopkins, Kier
Peter Haslam, NIA
Lord Martin O'Neill, NIA
Jon Taylor, Rider Levett Bucknall
Glennan Blackmore, Skanska
Paul Sephton, Skanska
Madoc Batcup, Synaps

1.3 Tour itinerary

The tour had a busy schedule, visiting the industry body Japan Atomic Industry Forum, (JAIF), contractors Taisei, Toshiba, Shimizu and steel fabricators IHI. J Power, TEPCO and JNFL hosted visits to two nuclear power station sites under construction plus a nuclear recycling facility. The delegation also met with nuclear industry members from BCS and OCAJI in a reception at the British Embassy. The full itinerary is shown overleaf.

Monday 7th March	
AM	Briefing from Henry Loo and Euan Low, Mott McDonald, on the structure of the Japanese construction industry. Japan Atomic Industrial Forum. Introduction to JAIF and overview of nuclear power in Japan.
PM	Toshiba Power Systems Isogo Engineering Centre. Introduction and overview of Toshiba and Isogo Engineering Centre plus an outline of Toshiba nuclear activities. Demonstration of plant construction planning tools (6-D CAD) and an explanation of the different nuclear plant models of ABWR, AP1000TM and 4S provided by Toshiba.
PM	Factory visit to IHI, Yokohama Works viewing the fabrication of containment vessels, pressure vessels and steam generator plant.
Tuesday March 8	
AM	Taisei Corporation Head Office. Overview of their nuclear construction activities.
Wednesday March 9	
AM	J Power - visit to Ohma construction site. TEPCO - visit to Higashi-Dori construction site.
PM	JNFL - visit to nuclear fuel cycle facility at Rokkasho.
Thursday March 10	
AM	Shimizu Institute of Technology. Introduction and overview of Shimizu nuclear project experiences, in particular Ohma power station. Followed by a review of the seismic bearing and isolation systems for buildings.
PM	British Embassy - NIA/CE presentation to BCS/OCAJI members by Peter Haslam, Don Ward and Henry Loo. Followed by a reception.
Friday March 11	
AM	Round table meetings with BCS/OCAJI members interested in the UK nuclear construction market or possible collaboration in third markets.

2.0 OUR FINDINGS

2.1 Japanese culture and the Japanese construction industry

Henry Loo (Constructing Excellence) and Euan Low (Mott MacDonald) kicked of the tour with an insight into the Japanese business culture, many of which insights were reinforced during the course of the week. The Japanese have one outstanding characteristic, total commitment. Work comes before any other activity. The company comes first. Tradition, culture, religion, education, social history – all contribute to the conscientious, loyal, single-minded and hard-working business culture of Japan.

Observations and what we were told

The key aspects of Japanese business culture are:

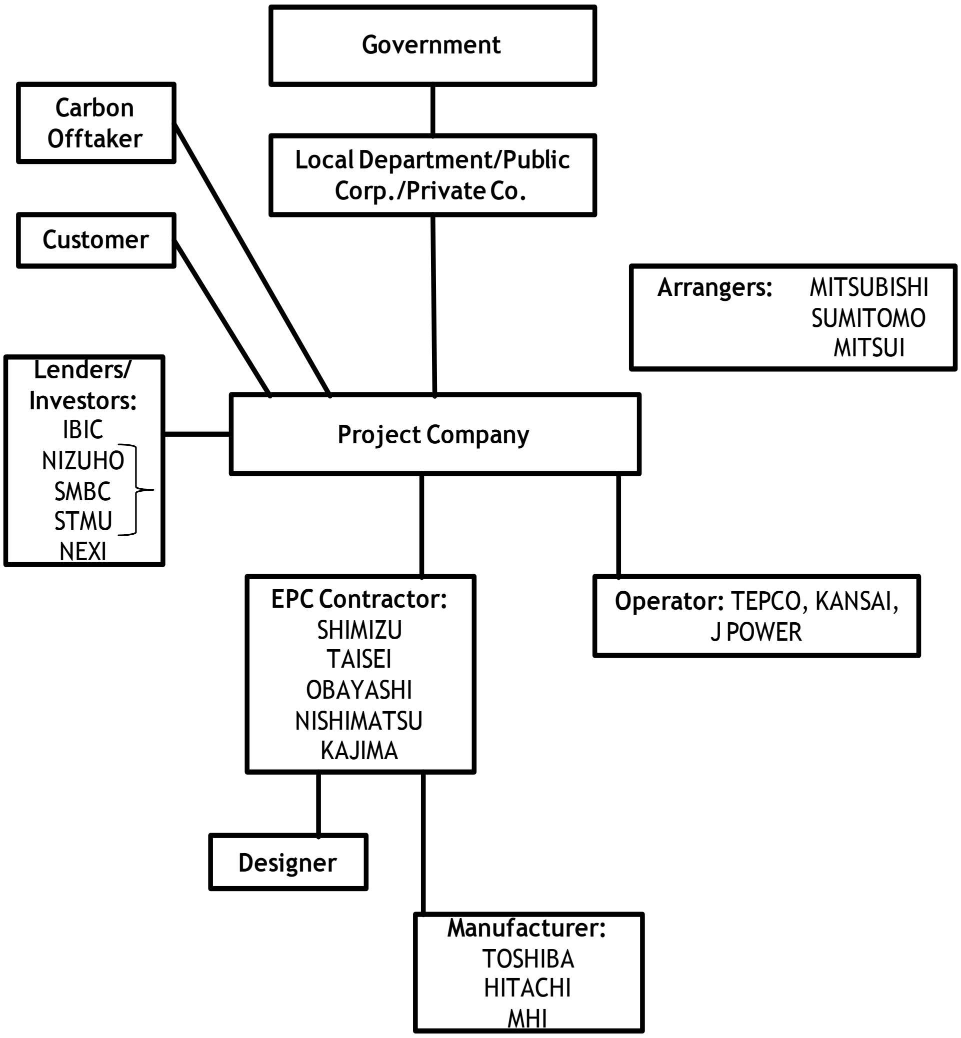
- Deep sense of self worth, honour and shame
- Strong respect for one another
- Inherent instinct to create a sense of order
- Self discipline and covert peer pressure
- Fastidious timekeepers.

This leads *inter alia* to:

- Low rates of crime and vandalism
- Cleanliness and tidiness
- Finishing projects late is taboo.

The Japanese construction industry had 542,000 licensed contractors in 2005 with a turnover of £240bn, and it employs 5.6 million people. However, the market has shrunk by nearly half since the peak of the property boom in the early 1990s.

The structure of the Japanese nuclear power sector is shown overleaf.



Observations and what we were told

Key features of the Japanese construction industry include:

- Five super contractors **Shimizu, Taisei, Obayashi, Takenaka** and **Kajima**, each with sales ranging from £8-12 billion pa. Over 50% of the business of these super contractors is pure Prime Contracting
- All major contractors have large R&D budgets. The 60 largest companies in Japan each spend an average of 0.5% of its turnover on R&D. Kajima for example, spent £50million+ on R&D in 2007 (just over 1% T/O). However, 10 years ago this was much higher at 4% of turnover. Innovation is a differentiator, hence all major contractors have R&D institutes
- There is great emphasis on training. New recruits rotate around different disciplines in their first year as interns.

How business is conducted in Japan:

- Repeat business is bedrock of operations
- Client satisfaction drives everything
- Fiercely competitive – but not just on price alone

- Payment in public sector projects tends to be paid on the basis of negotiation: 30% at commencement, 30% at structural completion and weather tight, 40% on completion.
- No retention on main contractors but held on sub-contractors
- Sub-contractors are paid upon logical pre-agreed stage completion, e.g. floor by floor
- Extensive use of IT in everything
- Use TQM feedback to benchmark and improve processes
- Earthquakes are a major driver to technology investment
- O&M data is fed back into design department
- Designs by clients' consultants are considered as briefs
- Detailed design is normally done directly by contractors in collaboration with supply chain
- M&E design is done in-house and let on a 'fit for purpose' basis, i.e. an output performance basis, not input specification.

Doing business with Japanese companies:

- Establishing trusting relationships is key to doing business with Japanese companies
- The Japanese are very integrated as partners; they discuss and share views amongst themselves. Therefore, it is important to talk to all the decision makers. This is best done on an elimination-of-objection basis.
- Japanese construction companies are very keen to export their capability in 2 sectors, rail and nuclear. However, they are struggling to compete on price due to the exchange rate of the Yen.
- Japanese government has doubled the Japan Bank for International Cooperation (JBIC) budget and changed ordinances to allow JBIC to lend to nuclear power projects, lend on certain infrastructure projects in developed countries and take equity stakes in certain infrastructure projects.
- Japan's Nippon Export and Investment Insurance (NEXI) is a state agency for insurance of export and foreign investment operations. NEXI is able to insure projects.
- General contractors are keen to leverage knowledge and experience but need partners to share costs and risks.
- Manufacturers Toshiba, Hitachi and MHI, are leading the drive in the nuclear sector but are resource constrained.
- Trading companies are only interested to be contract arrangers for nuclear, but consider risks too large to lead EPC or investment.

2.2 The Japanese nuclear power industry

The Japan Atomic Industrial Forum (JAIF) was incorporated in 1956. The objective of the organisation is to promote the peaceful utilisation of Nuclear Energy and Technology. JAIF has 480 corporate members. Its main activities are: enhancing understanding and promotion of public understanding; rationalisation of regulations; human resource development; promotion of international cooperation; and information services and liaison amongst JAIF members.

JAIF provided us with an overview of the nuclear industry's history in Japan, providing helpful context for the remainder of the tour.

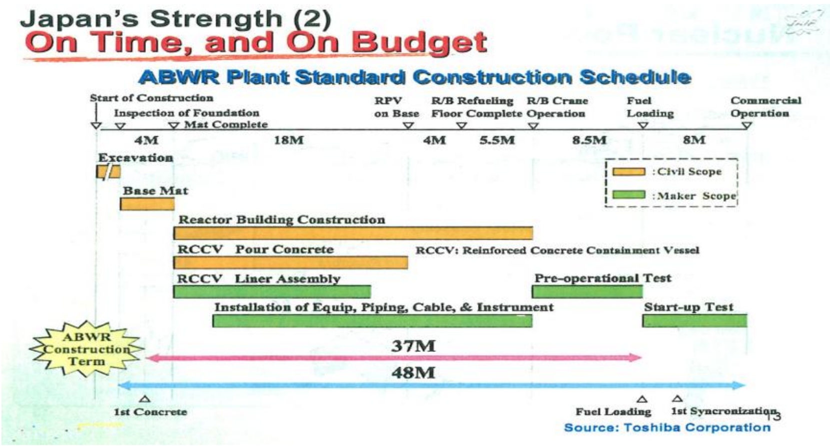
Observations and what we were told

JAIF international links:

- JAIF have established an international cooperation centre, JICC, in 2009. This is the contact and coordination point for countries outside Japan.
- JINED, established in Oct 2010, co-ordinates with JICC to draw up project proposals.

Japan's Nuclear sector:

- Japan has a balanced energy mix with 31% nuclear, 26% coal, 24% natural gas, 11% oil and 8% hydro power. These figures relate to the year 2000.
- However the oil crisis has invoked a strategy to increase Nuclear power. Japan's "Basic Energy Plan" June 2010 commits to increasing nuclear energy to 40% by 2020 reducing dependence on oil generated power.
- Within the same strategy there is a policy to improve capacity in existing plants to 85% by 2020.
- Japan currently has 54 Nuclear plants in operation, 18 of which have been in operation for more than 30 years (30 BWRs and 24 PWRs)
- It has 4 plants under construction (including a fast reactor) and 11 plants in planning stage.
- The next generation High Performance ABWR and HP APWR are planned to be brought into operation in 2030 and a commercial fast reactor before 2025
- The standard programme time for ABWR's in Japan is 37 months from first concrete to fuel loading (*source Toshiba Corporation*).



Seismic capability: we were quoted the performance of Kashiwazaki–Kariwa plants after the M6.8 earthquake in 2007. All seven plants were shut down safely with no damage observed on safety related structures or systems.[1] When questioned further at the end of the session we were told that the shutdown was initiated automatically and that electricity was maintained during the earthquake, by generators and alternative sources. ?)

Planning: we were told that local people tend to accept nuclear, this is helped by taxation funds which are channelled to supporting the local communities.

[1] As noted in the Acknowledgements, the M9.0 earthquake at the end of the week of our study tour had an altogether different level of impact.

2.3 Research and development in the Japanese construction industry

All the top companies in the Japanese nuclear and construction sectors spend around 0.5-1.0% of their turnover on in-house R&D.

The delegation visited two company research institutes, Toshiba's Isogo Engineering Centre and the Shimizu Institute of Technology. Both visits illustrated the emphasis on research and development (R&D) to gain a competitive edge. The detailed design, construction planning and construction methodology was developed in these establishments. Whilst "lean construction" was not specifically mentioned on these visits, these R&D institutes formed a crucial part of their continuous improvement process.

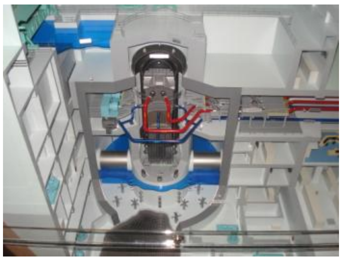
Toshiba's Isogo Engineering Centre

The delegation was hosted by Toshiba at their Isogo Engineering Centre.

Observations and what we were told

This is an example of Toshiba's investment in R&D. Here Toshiba supports the design, manufacturing and construction of Boiling Water Reactors (BWR), Pressurised Water Reactors (PWR) and its next generation LWR Fast Breeder Reactors (4S).

APR AP1000



ABWR

4S

The scope of activities here covers engineering, procurement and construction. This includes plant planning, component design, fuel cycle technology, general technology (including construction management, IT, CAE and procurement), advanced energy, control and electric design, system design and core and fuel design.

ABWR reactors' construction period is 37 months compared to 41 months for a PWR. This is achieved through all-weather construction methods, large pre-assembly blocks, modular construction methods and 6D-CAD. The ABWR also has an improved plant efficiency of 35.2% compared with 35.1% for the PWR design.

Toshiba has developed a new high-level construction planning system called 6D-CAD. This combines traditional 3D-CAD design information with material quantities, programme time and resources. The system can also be used with 3D information derived from laser scanning for positioning existing equipment. 6D-CAD has led to reduction in construction schedule times and optimum resource utilisation. Toshiba also use it for selection of modular packaging.

Toshiba focus their use of 6D-CAD optimization on high density component areas.

Shimizu Institute of Technology

The delegation also visited Shimizu's Institute of Technology, part of the Shimizu Corporation. Shimizu was established in 1804 and had Construction Orders of 1,118 bn yen (approx. £8.73bn) in 2010. It was involved in the construction of Japan's first nuclear reactor and 12 other nuclear facilities in Japan including the Ohma nuclear power station visited by the delegation.

Observations and what we were told

The institute has a budget of 6.5bn yen internal R&D plus 0.5bn yen in external R&D

Ground motion and soil evaluation, technology development (e.g. seismic isolation mechanisms, steel plate reinforced concrete containment vessels), structural design, and construction technologies (4D-CAD, large block modular construction methods) are the main areas of work for the Institute.

Outputs from the construction methodology research that were put into practice on construction sites such as Ohma were given as:

- 90% of piping was installed as modules
- 30% of all structural steel is pre-fabricated
- Extensive use of prefabricated modularisation was used. Modules, such as steel liner vessels, rebar, M&E control room modules, pipework etc, were generally fabricated adjacent to the works on sites and lifted into place by large cranes
- Supports for frames were embedded into concrete to remove obstructions to M&E pipe work
- Removed mezzanine floors
- Rebar is largely pre-fabricated
- Automated rebar fixing machine was used to place rebar in large mats
- Stair units were pre-cast and combined with temporary services
- CAD data was used by all.

Steel-plated concrete to replace traditional reinforcement and formwork for the Ohma turbine pedestal had been developed in Shimizu's Technology Institute.

Extensive modelling and rehearsal to test construction methods was carried out on mock-up models in advance of construction on site. This reduced construction time by 8-11 months and it also reduced member size by 10%.

The delegation also visisted the Taisei Corporation Head Office. Taisei is an international construction company that was established in 1873 with a sales turnover of 1,442 billion yen (approx. £11 bn).

Observations and what we were told

- Taisei have been actively involved in the design and construction of several nuclear power stations and nuclear fuel cycle processes. These include Ooi nuclear power station which had a pre-stressed concrete containment vessel and Tomari nuclear power station
- The planning time before the first concrete is poured is 2-3 years
- Changes in design are rare and are mainly only in pipework.

2.4 Manufacturing plant visit

The delegation visited IHI's Yokohama nuclear and chemical components works. IHI was established in 1853, had a nett sales turnover of 1,242 billion yen (£9.7 bn) in the year ending March 2010. Energy and plants operations is 26% of this turnover. Its other business areas include ship building, aero engines and aerospace, rotating and mass production machinery and industrial machinery.

Observations and what we were told

The works house one of the few giant precision machinery plants in Japan. Its principal equipment includes 5 Planomiller machines with capapcity upto 22m in length, 3 horizontal boring machines capable of handling 24m in length, 2 vertical lathes capable of handling 4.5m in diameter, 2 roller grinders capable of handling 10m in length and 2 gear cutting machines capable of handling 5.5m diameter. It also has a 60m x 30m x 6m assembly pit. It has manufactured various components for the nuclear industry:

- The reactor pressure vessel for unit 1 Fukushima-Daiichi nuclear plant
- The reactor pressure vessel for unit 1 Hamanaka nuclear plant
- The first reactor pressure vessel for Onagawa nuclear plant
- A 7210 KW forced draft fan Higashi Ogijima power plant
- The reactor pressure vessel for unit 6 Kashiwazaki-Karima nuclear plant
- Four storage tanks for the high level nuclear vitrification and storage plant for JNFL.
- Primary containment vessel of the Higashi-dori unit 1.

IHI supply 3 main components for nuclear power plants:

- Primary containment vessels up to 3700 tonnes
- Pressure reactor vessels up to 360 tonnes
- Piping systems up to 700 tonnes

The average manufacturing period for a nuclear power plant is 3 years

The capacity of the Yokohama works is approximately 3 nuclear plants per year.

2.5 Construction site visits

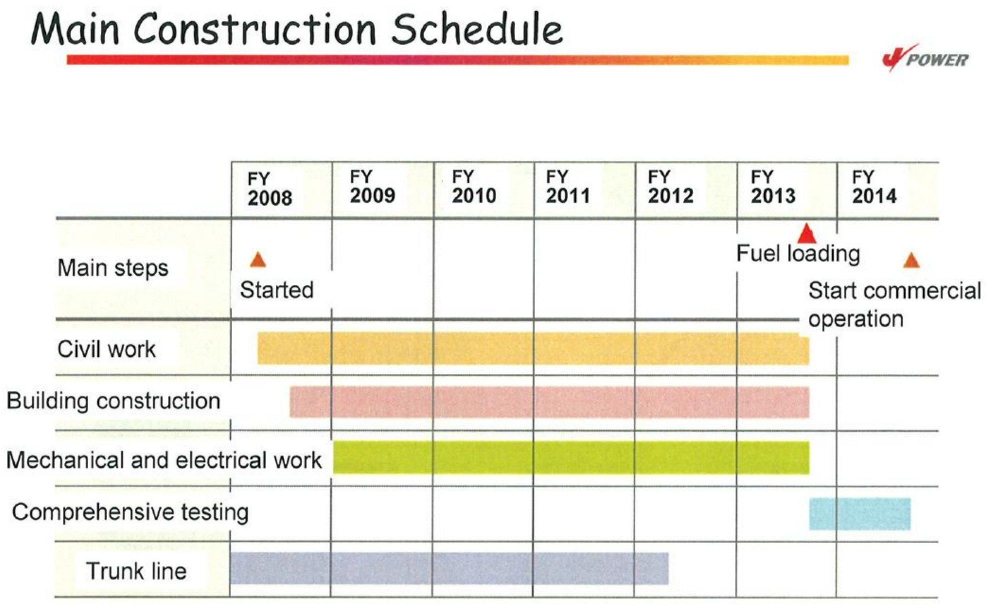
The delegation visited two construction sites, Ohma nuclear power station as guests of J Power and Higashi-Dori as guests of TEPCO. The works at Ohma were at an advanced stage while the main works at Higashi-Dori were in the early stages.

Ohma

The Ohma nuclear power station is a 1385 MWe Advanced Boiling Water Reactor (ABWR) and will be fuelled by mixed oxide MOX. The MOX fuel is a mixture of uranium oxide and plutonium oxide. The plutonium is extracted from recycled fuel from nuclear reactors. Apart from the Fugen experimental Advanced Thermal Reactor (ATR), Ohma will be the first Japanese reactor built to run solely on MOX fuel incorporating recycled plutonium. It will be able to consume a quarter of all domestically-produced MOX fuel.

Construction at Ohma started in May 2008 and commercial operation is scheduled for November 2014. At the time of our visit construction was 35% complete.

Image of how Ohma Nuclear Power Plant will look like at completion
Courtesy of J Power



Ohma nuclear power plant programme - *Courtesy of J Power*

Observations and what we were told

After 2 years from the start of construction 2000 people were working on site. Next year resources will peak at 2600. Currently there is a 6 day working week.

Total cost of the project is 470 billion yen (approx. £3.67bn)

The key improvements of the ABWR are internal reactor pumps, fine motion drive mechanism and an integral reinforced concrete reactor containment vessel lined with steel.

The delegation remarked on the relatively small footprint of this ABWR site.

A key aspect of the construction methodology used in this northern location of Japan was the all-weather structure to enable construction work to continue through the severe winter conditions. This was a significant structure (see photos below) with a sliding roof opening to facilitate access. This is estimated to save 2-3 months per year over 3 winters.

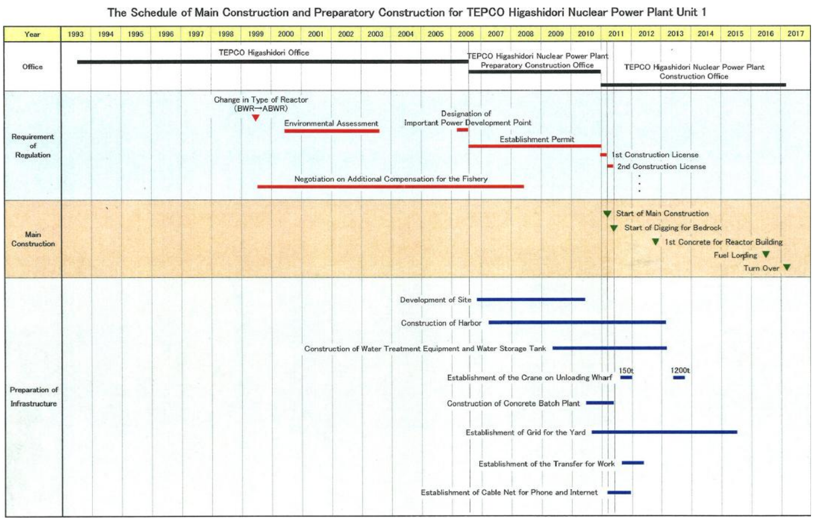
Other key aspects of the site construction were the modular assemblies in progress on on-site assembly areas. These modules were serviced by a 1000t capacity rotary track crane.

Examples of large-scale modular construction methods were the 700t pre-fabricated upper reinforcement mat to the reactor floor slab, the reactor containment vessel pre-assembled with reinforcement and pipework. The advantages are improved quality assurance, increased areas of work and speed of construction.

A steel plate concrete construction was used to replace conventional reinforced concrete in the turbine generator pedestal and the floors to the reactor building. This eliminated formwork and rebar fixing in congested areas greatly reducing on-site programme time from typically 11 months to 8 months. It also reduced member size by 10% (*see the section on Shimizu for further information on how this technique was developed*)

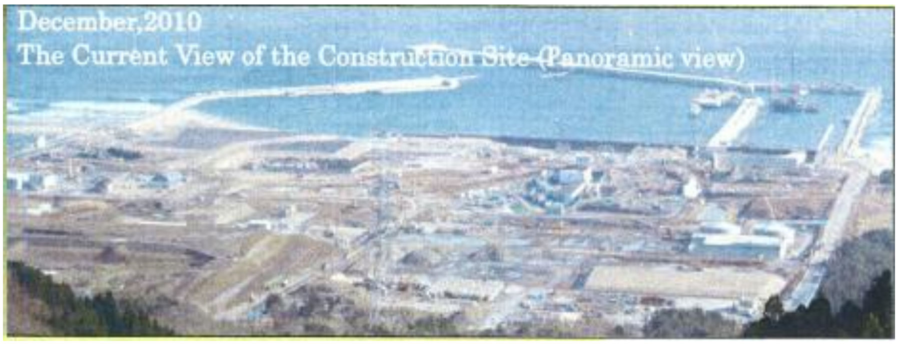
Higashi-Dori

Higashi-Dori is a 1385 MWe ABWR nuclear plant in the very early stages of construction. Main construction started in January 2011 and commercial operation is scheduled for March 2017. There is already a nuclear plant to the south of the site we visited which was completed in December 2005. The Higashi-Dori area will eventually house four nuclear plants, all to the Toshiba reactor design.



Higashi-Dori nuclear power plant programme

Observations and what we were told



The overall footprint of the facility measures 3x1.5 km

The Construction Programme from first concrete to fuel rodding will be 41.8 months

Main contractors are:

- Reactor and turbine - Hitachi and Toshiba JV (reactor pressure vessel Toshiba)
- Kajima – reactor building, Shimizu – turbine building

Design work was done separately.

All Contractors were selected "on cheapest or most impressive" bid. Toshiba and Hitachi were invited to bid separately, However, decided to form a JV

The infrastructure works have been underway for many years, with the harbour construction largely established, roads, water treatment and water storage tanks, concrete batching plant and main administration building completed.

Approx. 500 people are currently employed on-site and it is expected that resources will peak in 2014/15 with 1500 to 2000 people on-site. It is anticipated that there will be a transfer of skilled workers from the nearby Ohma site.

2.6 Recycling facilities visit

The delegation also visited the nuclear fuel recycling facilities at Rokkasho. This visit was hosted by Japan Nuclear Fuel Ltd (JNFL), a private venture led by the nation's nine electric utilities. Three types of facilities currently operate at Rokkasho, uranium enrichment, vitrified waste storage, and low-level radioactive waste disposal. Two further facilities are under construction on the site. These are a reprocessing plant currently undergoing final commissioning tests, and a mixed oxide fuel fabrication plant. The completion of the last two plants will achieve Japan's strategy of ensuring a "semi-national" energy supply. A deep underground disposal facility is planned to start operation somewhere between the 2030s and 2040s.

Observations and what we were told

JNFL currently employs 2400 employees and 2000 contractors' people across the facilities.

Uranium Enrichment Plant:

- JNFL owns and operates a large-scale uranium enrichment plant at Rokkasho. The enrichment plant was completed in 1992 and has an operating capacity of 1050 ton SWU (separated work unit) per year. Total production of enriched uranium is 1681t UF_6 as of 28 Feb 2011.

High Level Radioactive Vitrified Waste Storage Plant:

- Operations started in April 1995
- Until the reprocessing plant is completed, Japan's spent fuel is reprocessed in France and the UK. Reprocessing generates waste liquid which is solidified with glass in stainless steel casks.
- The design capacity is 1,440 canisters which will ultimately be expanded to accommodate 2880. Currently the plant has received 1,338 canisters (28 Feb 2011), mainly from France.

Low level Waste Radioactive Disposal Centre:

- Operations started in December 1992
- The operation and maintenance of nuclear power stations generates low level waste such as work clothes, gloves and cleaning fluids. Liquid waste is boiled and concentrated by mixing with cement or plastic then sealed in drums. Flammable waste is burned and sealed in drums. Metals are compressed or melted down then sealed in drums. These drums are stored in interim sites at nuclear power stations before being transported to Rokkasho
- The drums are stacked in containers sealed with reinforced concrete lids and buried in a bentonite/sand mix. Finally a covering of 4 to 9m of soil is placed on top
- The design capacity of the disposal centre is 3 million drums (200 litre each)
- Currently there are 229,000 drums stored (28 Feb 2011).

Re-processing Plant:

- The reprocessing plant is currently under final commissioning with commercial operation expected to start in October 2012
- The capacity of the reprocessing plant will be 800t of uranium per year. This is equivalent to the capacity to reprocess the spent fuel from thirty 1,000MW-class nuclear power plants.

MOX Fuel Fabrication Plant:

- Construction started in October 2010
- The nuclear fuel used for power generation in a nuclear power plant contains residual unburned uranium and plutonium newly produced in the reactor. This spent fuel can be reprocessed and utilized as new fuel. Recovered uranium is mixed with natural uranium or depleted uranium and is made into MOX (mixed uranium and plutonium oxide) fuel.
- The design capacity is 130 t HM per year
- Start of operation is planned for March 2016.

3.0 CONCLUSIONS AND RECOMMENDATIONS

3.1 Were our objectives met?

Of the specific objectives of the tour delegates prior to the tour (see page 3), the great majority were achieved. It was difficult to achieve any comparison between the Japanese and South Korean nuclear construction industries, this would require a similar study tour to South Korea to compare and contrast, but otherwise most objectives were clearly met. We heard about and witnessed for ourselves much industry best practice, innovation, collaborative working, right first time, and processes for capturing learning and continuous improvement. We saw many examples of what in the UK we would call "lean construction" techniques, however it is interesting that the Japanese see these as just sound project management practice and not worthy of separate note.

The final objective of Constructing Excellence, to continue developing links with the Building Contractors Society of Japan, was also thoroughly achieved. The Thursday night reception was extremely well attended and cemented good industry-level and company-level relationships for the future. Unfortunately, the horrific events of the Friday afternoon, the earhquake followed by the tsunami, will inevitably impede progress as the Japanese concentrate on rebuilding their own country, but in due course we hope that Constructing Excellence and individual tour delegates will be able to build on these excellent relationships.

3.2 Summary of lessons learned

The following table summarises our main observations from the study tour under the headings of Engineering, Construction, Site management, and Culture.

Engineering BWRs seem a lot simpler than PWRs allowing greater simplification • Fewer major components (piping, pumps, no steam generators) • Reactor pressure vessel is lower pressure and can be manufactured in less specialised facilities • Reactor Island is more compact – making cranage and access easier. Client designs treated as design briefs O&M feedback taken into learning and future design Re-use of key design elements Designed and engineered to be built Integration of both civils work and M&E High use of information systems and design tools (e.g. 6D CAD) Close cooperation and information sharing between parties Highly modularised in design Steel plate concrete solutions (easier to build) Many Japanese standards (not internationally recognised)
Construction Significant focus on construction planning and sequencing before construction starts (c.1 year in planning activities) Construction and build: • Undertaken from inside out

- Activities sought to be at ground level – "We avoid work at height" (Toshiba)
- Seek to using large modularisation techniques

Use of simulation and check builds (assemble in factory) before on site
Build of permanent structures early to avoid temporary structures
All contractors use same data tool/ systems
Driving to 37 months construction timescale (from rock inspection to commercial operation, ie before rebar placement for base mat) – much done off site
Extensive multi-discipline modularisation with M&E and civils contractors collaborating
Drainage pipe work, cables and temporary flushing pipe work buried in base concrete to prevent construction openings being left open
Using all weather construction temporary buildings over construction site – nuclear island built inside a massive temporary steel frame building
Planned around weather constraints using all weather approaches

Site management

Infrastructure in place before construction starts
Designed to be minimum time on site and do as little as possible on site
Activities moved off site where plausible
Very tidy organised sites

- Temporary cables on racks off floor
- Laydown areas racked
- Very early metalled construction roads – even during earthworks

Extensive use of modularised rebar cages.

- Qualified techniques and tools for assembling cages and mats so they can be lifted.
- Extensive use of engineered jigs (appear reusable for different sites) to enable lifting of rebar modules – eg base mat rebar lift and lift of reactor building containment roof rebar. rebar.

Use of constructed "harbours" for each site
Use of very large cranes
Not breaking ground in winter and weather pauses where appropriate

Culture

Naturally collaborative despite contract and structure type
Rely on relationships primarily and they invest in this
Shared focus on outturns for client
Difficulty in reporting bad news as try to resolve
A data rich environment and highly visible with morning briefing and tool box talks to the team
A proud people and seek to be the best

3.3 Recommendations for the UK nuclear construction programme

The whole Japanese approach is difficult to copy, the fundamental national culture determines certain behaviours which are hard to replicate otherwise. But to emulate the success of Japanese nuclear construction, and to enable the UK nuclear construction programme to deliver on time and within budget, our 'top 10' recommendations for the UK programme are as follows:

1. **Develop robust strategies for delivering design, construction and commissioning**

2. **Design equally for construction and commissioning not just for function, from the beginning of the design lifecycle**

3. **Integrate design elements, eg civils with mechanical and electrical erection aspects**

4. **Plan Plan Plan Do – plan the construction process in detail and then install right-first-time**
   - **modelling and simulation to optimise construction**
   - **practice assembly in controlled conditions before going to site**

5. **Construct from inside out, not outside in and not at height**

6. **Modularise construction, do as little on site as possible**

7. **Collaborative working is a state of mind and requires all to do it**

8. **Focus on quality top to bottom – safety follows**

9. **Avoid the use of temporary structures (but consider all-weather construction structures)**

10. **Use common information/data systems - 'centre of truth'**

In summary, success requires the early involvement of as much of the supply chain as possible, then plan-plan-plan together to lean the process, then do, right first time.

In short, **collaborative working**.