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EUROPEAN PRESSURISED REACTOR AT OLKILUOTO 3, FINLAND

BRIEF & INTERIM REVIEW OF THE

POROSITY AND DURABILITY PROPERTIES

OF THE

IN SITU CAST CONCRETE

AT THE

OLKILUOTO EPR CONSTRUCTION SITE

CLIENT: GREENPEACE INTERNATIONAL

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CONDITION OF THE IN SITU CAST CONCRETE AT THE OLKILUOTO 3 EPR CONSTRUCTION SITE

SUMMARY

I*n this Review I examine the present information available in the public domain relating to the condition of the in situ cast concrete base slab at the European Pressurised Reactor (EPR) construction site at Olkiluoto.*

From the very sparse information publicly available, I arrive at a number of provisional conclusions and recommendations, in addition to which I have to admit at being somewhat baffled as to why

- *i) such an important material characteristic as the permeability of the concrete at a crucial location could have been prepared and placed in a defective and non-compliant condition;*
- *ii) the nuclear safety regulator STUK, some 8 months after being notified about the non-compliant concrete, is still investigating and has yet to publicly report its findings; and why*
- *iii) public accountability of all of the organisations involved seems to have been passed by.*

Overall, I find that STUK seems to have lost focus on this particular issue – it should have recognised and dealt with the concrete non-compliance much more decisively and certainly earlier – these delays and apparent inability to effectively regulate the Olkiluoto 3 project may well be rooted in its very hurried and, in my opinion, ill-prepared assessment of and recommendation for the issue of the Construction Licence early in 2005.

BACKGROUND DEVELOPMENT

In or about March 2006 concern about the quality of the concrete cast at the Olkiluoto site was first reported in two trade journals.[1,2] One of these journals, Tekniikka & Talous, reported that the Finnish nuclear safety regulatory authority (Radiation & Nuclear Safety Authority - STUK) had already underway an investigation into the on-site supervision, quality assurance and cured characteristics of the placed concrete.

At that time Large & Associates[3] was instructed by Greenpeace International to provide an independent assessment of the situation without further delay. This was commenced by contacting each of the parties involved requesting further information.[4]

However, the response to date to these requests has been disappointing, insomuch that:

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1 i) Nucleonics Weekly and ii) Tekniikka & Talous.

2 6 October Issue of Nucleonics Weekly reports some difficulties with the base slab concrete pour much earlier than *"The base slab, or foundation slab, is to be poured in three parts, STUK officials said. Esteve said that after pouring the first, small part of the base slab in August, Framatome decided to change the composition of the concrete for the Olkiluoto-3 base slab to slow down the curing process for the next and biggest pour. That pour was scheduled to start at the beginning of last week. Esteve said that Framatome didn't think it had to clear the new concrete composition with STUK because the change was "minor" and the additive in question had been approved by other Finnish authorities. But STUK said its regulatory guides on nuclear safety required specific approval for a change in concrete composition before pouring of the base slab. Framatome thus had to wait for the results of tests of the compressive strength of the concrete, based on samples, and submit them to STUK, causing a delay of about 10 days, Esteve said. STUK gave its approval Sept. 30 and the concrete pour began about mid-day Oct. 3."*

3 I am John H Large. I am a Consulting Engineer, Chartered Engineer, Fellow of the Institution of Mechanical Engineers, Graduate Member of the Institution Civil Engineers, Member of the British Nuclear Society and a Fellow of the Royal Society of Arts. From the mid 1960s through to the late 1980s I was employed as a full-time member of the academic research staff at Brunel University on behalf of the United Kingdom Atomic Energy Authority (UKAEA) and other government agencies undertaking research in the nuclear area. In the civil engineering field, as well as teaching advanced materials In the Brunel University School of Engineering. In my Consulting Engineering role I have conducted a number of investigations into concrete quality problems arising in commercial civil engineering projects underway and I have been involved in cases of concrete failure, both aggregate alkali attack and high-alumina degradation in structures in the United Kingdom

4 Large & Associates Memo, M3149-A1 to Petteri Tiippana, STUK of 17 March 2006.

PARTY	SOURCE INFORMATION	DATE	RESPONSE
STUK	Regulatory Position, all data and documents unless subject to obvious commercial confidence restraints.	17 March 30 March 10 April 02 May 11 May 25 May 03 June	Generally cooperative and promising but the date on which information would be provided progressively being set back, with over two months of set-backs, but with the promise of mid to end June 2006 - finally STU states on 3 June that it is unable to release documents cited by S Matala because the STUK review is ongoing.
Teollisuuden Voima Oy	TVO investigation and, particularly Helsinki University report	30 March	Courteous refusal to provide information
Forssan Betoni Oy	FBO investigation and, particularly Helsinki University report	30 March	No response whatsoever
Prof Penttalla, Helsinki Uni	Helsinki University report of assessment of test results	30 March	No response whatsoever
Seppo Matala	4 assumed detailed reports into the actual test results from concrete samples extracted from OlkiluotoTest.	11 May	No response whatsoever

My requests for further information have been met either with stony silence or, at best, a series of excuses and failed promises. So much so that now, over two months since my first request, virtually nothing has been made available in the public domain.

UNDER-SPECIFICATION OF THE CONCRETE

As shown in the above tabulation, very little officially substantiated information has been made available about the concrete although press reporting, albeit sometimes speculative, suggests that the quality of the concrete cast in certain parts of the base slab of the reactor area is unsatisfactory insofar that its *'porosity'* is not within the concrete specified[5] for the Olkiluoto project.

Contrary to common belief, cured or hardened concrete has a low resistance to chemical attack with the most significant forms of concrete degradation associated with carbonation and the ingress of chlorides and sulphates.[6] Essentially, chemical agents react with the hardened cement paste (CSH gel) so the components of the cement play an important role in the longer-term resilience of concrete against chemical degradation. Since the aggressive chemical has to migrate or leach to the site of attack, the resistance to attack improves with increased *im*permeability - this is the reason why, for the Olkiluoto 3 reactor base slab designed to operate for 60 years,[7] strict compliance with the permeability specification is so important.

The principal safeguard adopted against chemical attack is to minimise the voidage volume and the connectivity from void to void, that is the raising the *im*permeability of the finally cured concrete. In effect this is controlled by a number of indirect means at the concrete mixing and curing stages, such the type and quality of cement, the amount and type of binder used in the cement, the concrete additives including aggregates and hardeners, etc., curing environment, the pre-mix water-cement ratio and so on. Because of the range of variation expected in each of these constituents, arising from where they are

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5 The Olkiluoto concrete specification for the base slab is not available, although most probably the Finnish concrete codes have been adopted, these are SFS-EN 206-1 with the exposure classes XS1 and XA1.

6 Two common forms of chemical attack are from sulphates and chlorides:

Chlorides, via seawater, groundwater and salt laden air at coastal localities, can infuse into the body of the placed concrete by absorption though its surface, by capillary attraction within interconnected voids, and directly via cracks and fissures in the concrete with the chloride ions readily destroying the passive oxide film that protects the steel reinforcement; a further electro-chemical process may be supported resulting in accelerated corrosion; micro-cracking associated with the ingress of carbon (carbonation); and a reduction in the resistance to sulphate attack. The products of these interim term reactions are about, on average, twice the volume of the parent compounds, so micro-cracking within and overall expansion of the concrete develops over time leading to increasing permeability and a reduction in the durability of the placed concrete.

7 With an additional concrete base service life of 30 to 100 years in account of possible delays to complete decommissioning (dismantling) of the reactor island when generation has ceased.

individually sourced and how they are preprocessed, the standards and codes specifying the limits of concrete preparation and cured define compliance in terms an envelope within which the whole has to conform.

So far nothing has been made officially available from STUK or the other parties involved, although Lemminkäinen has stated[8] that the *'concrete's long-term durability has been studied by Finland's foremost authority in the field of concrete technology, Dr. Vesa Penttala, Professor of Building Materials Technology at Helsinki University of Technology'*. However, there is a leaked copy[9] of Penttala's report,[10] from which it seems that the water-cement ratio for the Olkiluoto 3 base slab concrete mix was too high, reaching 0.64 in some in situ taken samples compared to the maximum permitted ratio of 0.5. In this respect alone, the placed concrete ought to be considered not to conform to the prerequisite code or specification for the Olkiluoto 3 construction.

REPORTED DURABILITY OF THE CONCRETE

However, in his report Penttala argues that the effect of a high water-cement content can be reinterpreted to demonstrate that the placed concrete is acceptable and that no further treatment is required to enhance its durability (ie to additionally surface-seal to lower its permeability). Indeed Penttala, in an approach that might be best described as *'cherry picking'*,[11] goes further to suggest that the quality assurance codes may be modified for the Olkiluoto case to offset the potential effect of the water-cement ratio in that the furnace slag binder[12] is of greater significance than that accounted for in the code. This work mainly interprets and relies upon the laboratory testing and trials of the Olkiluoto 3 concrete samples by Seppo Matala, although none of the four reports referred to are available in the public domain.

However, if taken at face value and ignoring the somewhat absurd comparison of Mercedes Benz and Lada cars proffered by Penttala,[13] overall this leaked report seems not much more than that of seeking out and contriving a possible argument for acceptance of an out-of-code compliance. Penttala's approach does not seek to validate the Olkiluoto 3 placed concrete in terms of the specified codes but arrives at the conclusion that the convolution of materials and practises adopted for the concrete mix preparation on the Olkiluoto 3 construction site, almost as chance would have it, has resulted in a perfectly acceptable and durable concrete.

APPLICATION TO THE NUCLEAR POWER STATION OLKILUOTO 3

Drawn from the very limited information available, in my opinion and in conclusion, the concrete and related issues to placed concrete at Olkiluoto 3 are:

- **Facts of the Matter**

  So far as I can reliably ascertain the facts of the matter are:

  - Around early October 2005 the in situ casting of concrete to the reactor area base slab was completed.

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8 http://www.lemminkainen.com/news.asp?Section=1506&Item=13796 of 8 March 2006

9 Being leaked, obviously, the copy of the Penttala report cannot be irrefutably relied upon.

10 This report refers to a few test results from the unobtainable Matala report suggesting one detail of the non-compliance of the placed concrete, see *Statement Concerning The Durability Properties Of Concrete Produced By Cement Type Cem III/B-SR In Exposure Classes XS1 And XAj Of The Olkiluoto Nuclear Power Station 3 Base Slab*, 2 March 2006 14 pp.

11 In certain and important respects, Penttala cherry picks his way through the codes arguing that the code accounts for the poorest performing cements whereas the Olkiluoto cement is superior in this respect (>10% compared to 7% calcium carbonate) with the furnace slag content being 77%; he recalculates the water-cement content from 0.64 reported to 0.62 which is to be compared with the 0.5 ratio of the code; and there is a somewhat abstract statistical abstraction to Portland cements.

12 When cement hydrates the principal binder produces is calcium-silicate hydrate (CSH) although a percentage of this may be calcium hydroxide or free lime which can contribute to durability problems – with the inclusion of of silicate rich furnace slag there is a greater production of CSH with a denser cement pasts and reduced permeability.

13 As a consequence, any suggestions of protecting the concrete surfaces e.g. with coatings are unnecessary. As a simplification of the durability, aspects of the base slab concrete one could find an analogy in car selling business. Situation is somewhat similar to the case in which customer has ordered a Lada and gets a Mercedes Benz but the customer still complains that it is of wrong color.

- Shortly thereafter it was reported to STUK that there were *'minor aberrations'* to the quality of the concrete although, subsequently, it was admitted that the extent and level of concrete porosity was more serious than originally believed.
- Although concrete sample test results have not been made publicly available, the increased porosity is believed to relate to the high water-cement ratio deployed in the preparation of batches of the concrete mix (0.64 compared to the materials code maximum of 0.5).
- Now, some eight months following the initial notification of the presence of non-compliant concrete in the reactor base slab, the nuclear regulator STUK has yet to publish the findings of its investigation into this licensing issue.

o **Quality Assurance**

The fact that concrete was mixed and placed in areas of the Olkiluoto 3 construction site was not compliant with the design specification (here assumed to be SFS-EN 206-1) is of great concern:

- This is because the regulator STUK has to ensure and rely upon absolute adherence and compliance to design and material specifications throughout the construction process, else the quality assurance regime for detailed aspects (like the concrete considered here) and the nuclear plant overall could be placed in jeopardy.
- Non compliance with the Olkiluoto 3 design and, implicit with this, the terms of the Construction Licence could result in substantial deviations in the design of the final, commissioned nuclear plant, some of which could have, singly or in combination, important nuclear safety consequences.

Put another way, it is of no matter whether the concrete is of acceptable quality (albeit a rather doubtful and unproven claim by Penttala at this stage) but more the fact that quality assurance procedures have failed at this relatively early stage – this casts doubts on the surety of the plant construction and, overall, the integrity nuclear safety case.

Recommendation 1: The long awaited STUK report into the Olkiluoto 3 concrete issue should i) examine and report upon how it was possible a non-compliant material (and the associated preparation and quality control practises) to be installed at Olkiluoto 3, and ii) assessment should be undertaken to determine the risk of other incidence of non-compliance that may have occurred or could occur in future in the Olkiluoto 3 construction programme (ie beyond the concrete issue).

o **Role of the Regulator STUK**

If STUK was unaware of the non-compliant concrete only to discover this at a later date after the concrete had been placed then

- An element of complacency must have corrupted the quality assurance regime thereby allowing the non-compliant concrete to be placed *without* STUK's agreement. The opportunity for this may have been seeded much earlier during the Construction Licence process, this being a somewhat hurried route towards issuing the Construction Licence in February 2005.[14]
- The programme of and conditions attached to the Construction Licence, ie the 'Hold Points', should have included a check on the ability and skills of the contractor to provide a compliant concrete prior to proceeding with the concrete placement programme – if this had been in place then the non-compliant batches of concrete could not have been placed.

[14] *The European Pressurise Reactor at Olkiluoto, Finland – Review of the Finnish Radiation & Nuclear Safety Authority (STK) Assessment Report*, R 3123-A2, September 2005, http://www.largeassociates.com/R3123-a2%20final%20Issue.pdf

Recommendation 2: These potential shortfalls could stem from the licensing process itself and, accordingly, STUK should carry out a thorough review of the licensing process, making those post-licensed amendments required to maintain absolute public and peer confidence in the licensing process adopted in Finland.

However, if as it seems STUK was fully aware of concrete problems during the casting period, that is as early as or prior to October 2005[15,16] then the implications following from this are very serious because:

- STUK would have knowingly permitted a deviation from the design specification for it to be addressed at a later date with its investigation commencing in March 2005 or thereabouts.
- This situation could well have compromised STUK's independence because now there may arise some difficulties for it to draw back from its earlier permission allowing concrete placement to proceed.

That said, the above opinion is drawn from my assumption that the press reporting of earlier concrete problems[2] (October 2005) is reliable and that the concrete *'problem'* identified then is that being considered here.

Recommendation 3: Since this relates to the role and competence of the regulator, this aspect of the Olkiluoto 3 concrete issue should be thoroughly investigated and reported upon by an independent body.[17]

That said, STUK is supposedly an 'independent' regulator but the evidence examined here (albeit incomplete because STUK itself will not release the information) points to STUK's failure to adequately monitor and manage the terms of the Construction Licence, thus it might be appropriate to fundamentally review the nuclear regulatory position in Finland, doing so in an entirely transparent and publicly accountable way.

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15 Nucleonics Weekly, 6 October 2005

16 Or first detection could have been earlier if the April 2005 Nuclear Safety Review is referring to permeability which refers to surface cracking and holes in the base slab. See also Satakunnan Kansa of 2 March 2006 in which TVO acknowledges the concrete porosity problem to have been known shortly following completion of the base slab cast of 3 October 2005 and that it reported this to STUK shortly thereafter, although then the concrete problem was believed to be only a minor aberration. However, the Rakennuslehti-Magazine quotes STUK as acknowledging the concrete problem to be larger than originally thought.

17 Else *quis custodiet ipsos custodes*?