**Fw: Muskrat Falls - Horizontal Slipforming**
Darren Protulipac to: John Mulcahy 05/30/2016 01:17 PM

for your comments

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You owe it to yourself, and your family, to make it home safely every day. What have you done today so that nobody gets hurt?
----- Forwarded by Darren Protulipac/NLHydro on 05/30/2016 01:17 PM -----

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Date: 05/29/2016 05:14 PM
Subject: RE: Muskrat Falls - Horizontal Slipforming

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Tod,
Many thanks for your email and earlier received proposal by the contractor re the above which I had glanced over in anticipation that you may wish to call me during the meeting.
Regarding the slipformed u/s and d/s kerbed facing I can tell you the following:

- First used at Upper Stillwater dam in Utah USA (ref MDA) in latter 1980's. Dam was about 800m long 80m high +1millm3 RCC with a wide bottomed valley so that long runs of the slipform were possible. The slipform and space for the CVC transporting truck (about 25m) meant that at the end of the run the last 25m had to be formed up and poured as a separate operation. The stepped spillway (approx. 25m3/m unit flow at PMF) was done by the slipform together with the non spillway sections. The dam has only spilled small flows - <500mm). It has a severe climate environment (80F to 20F or less) has no transverse induced joints and as a consequence developed 13 transverse cracks with one about 10mm open which took 3 campaigns of sealing, eventually installing a steel sheet across it (crest-fdn) in a slot developed by intersecting drill holes. The slipformed profiles were the same as now proposed for Muskrat (stepped d/s)and only allowed 2 lifts if RCC /lift of facing, i.e. 2 lifts /day with a delay of about 9hrs lag time for the RCC placing against the facing concrete so it was stiff enough for the RCC.
- Next used at New Victoria Dam in WA Australia 1990 - a 52m high 122,000m3 RCC (ref MDA and myself-for the contractor). Crest length about 350m. Same design as Upper Stillwater. Transverse joints were introduced by steel sheets driven into the RCC (normal way) and 'cut' manually into the CVC facing. Not feasible to place a waterstop into the slipformed CVC facing so a Carpi strip membrane was installed over the outside surface of the facing on line with the transverse joint. Done on completion of the dam and had to be commenced from

a socket excavated in rock at the toe of the dam. A very costly excercise (then about A$1000/lm-personal info from Contractor to me). Minimal leakage from these joints. Don't know its spillage history, but suspect it will not have been very much or large

- Next used at Porce II dam in Colombia 1994-8, 118m high 1.22mill m3 RCC (ref MDA and myself- as a member of the Board of Consultants). Same arrangement as for New Victoria with Carpi strip membrane installed on completion over the transverse joints. A very slow and costly exercise, mainly due to the slipformed offsets along the face arising from the inclined upstream face (about 0.2:1) and the need to dig access shafts down through the fill placed as part of the diversion against the u/s face – 6-8m deep in places then excavate the rock socket for commencing the membrane strip.

Numerous drying shrinkage cracks occurred within the kerbing which were of particular concern on the u/s face. Further because the RCC was placed flat without any drainage slope to shed rain and lift surface debris/washwater etc and being 'boxed in' by the facing a pond resulted so that the RCC lift surface had to be drained by vacuum trucks (3 required) !!! this was a serious delay to RCC placing especially during the wet season when storms of +/- 50-100mm were encountered. Drill cores were extracted through the RCC when about 70m up through the upper 20 odd m of RCC . Lift joints were found to be largely un-bonded (50%) and some drill holes did not hold water when filled – drained down as watched! Grouting was attempted but was not deemed successful. It was consequently estimated that the seepage rate from the dam would be about 300l/s. Contractor ASTALDI was thrown off the project (as mentioned to you all earlier), the work was re-bid to complete the upper 30-40m and awarded to Dragados who completed the job in short time and successfully. Ultimate seepage through the dam was only 30 l/s due it was believed to the "impervious" u/s slipformed CVC – despite the shrinkage cracking.

- To my knowledge this slipformed type of facing has never been used (or considered) for any other RCC project since.
- Although it might appear to be a solution to Muskrat (freeze thaw, reduction in labour to set forms etc) the added complications of the transverse joints, shrinkage cracking, delays in placing RCC against early formed facing, concern and experience of poorly compacted adjoining RCC and its bonding to the facing are all detrimental and concerning/unsolved problems. Why has it never been used since – easier, quicker and cheaper ways, and of course GERCC was 'announced ' to the RCC world in my paper at Chengdu in April 1999, shortly after Porce II, although in China it had been tried at some earlier projects.

I am attaching a couple of photos from the above 3 jobs for your interest. I also suggest you talk to MDA (Malcolm).

My own opinion is that you MUST bear in mind that Muskrat really only has 2 problems – **1**-the time available to place the RCC and construct the dam is VERY VERY short – winter won't wait for you, and **2** - the EXTEME cold and freeze thaw issues. All other design and construction issues have to ensure these 2 points are not adversely affected.

Regarding the question of mix design and spec for the slipformed CVC – sorry I can't help you there but Malcolm will have these from the 3 dams mentioned in his system. The CVC should – like GERCC - not be prone to drying shrinkage cracking and should have similar thermal and elastic (Young's) modulus as the RCC against it and should gain strength rapidly so the RCC can be fully compacted and bonded to the facing (any seepage filling honeycombed RCC against the facing could well freeze and cause a longitudinal crack detaching the facing from the RCC body of the dam).