CRACKED CONCRETE CASING

The first, very large propeller unit in the new 3-unit powerplant was ready for commissioning, and the engineers were anxious to proceed with watering up the concrete semi-spiral casing. Construction of the powerplant had required several years, and had preceded on schedule, with no significant problems, no doubt due to the wealth of experience the construction crew and design staff had obtained over the past few hydro projects. Evening was approaching when the order was given to crack open one of the headgates to flood the casing. This task completed, the crew retired for the night, leaving the plant unattended.

Next morning, the first engineer into the plant heard the auxiliary sump pump running, and noticed a warning light on the control panel, indicating high water in the sump. He ran down to the sump and on the way noticed that the drains from the turbine floor were flowing full. The sump was also near full, with both pumps operating. Returning to the turbine floor he was astounded to see the whole floor covered with about three centimeters of water, and water spouting up from several concrete pour joints on unit #1. Running back up to the control room, he closed the headgate and informed the chief commissioning engineer of the situation. If was decided to empty the casing and conduct a detailed inspection of the concrete - which only revealed a few hairline cracks and the usual shrinkage cracks.

Next day, the casing was again watered up, and seepage started to emerge from pour joints and from two large cracks between the unit centerline and the end wall, which opened up as the casing was pressurized. What had gone wrong?. In some places, water was spouting up by 10 to 15 cm. in a volume which was more than sufficient to cause concerns as to the integrity of the casing. A quick survey of the cracks and leakage was carried out, photographs taken, and the casing was again dewatered. The design team was informed, and was naturally incredulous, since the design had been checked by the consultant's senior engineers and also reviewed by the utility's staff. However, the team again checked all calculations and the input to the finite element program which had been used to compute the stresses in the large complex casing - to no avail, no errors could be detected. The concrete pour drawings were also reviewed, and construction records scrutinized, all of which indicated that the reinforcing was installed as required and all concrete strength tests were well above specification levels.

As a last resort, it was decided to undertake an independent review by an expert with many years of finite element design experience. His initial appraisal indicated that all was on order - but the evidence at site showed that something was seriously wrong. But what?. The input to the finite element program was correct, and the program itself was a recognized industry standard. So, if not the program, what about the assumptions?.

This is where the error was found!. The old garbage in - garbage out problem. The three unit powerplant was built in a large, deep pit excavated into hard granite. The turbine floor was almost 6 meters in depth, and for this depth of concrete to deflect, there must be some movement at the top corner. The surrounding hard granite had a modulus of elasticity much higher than the powerplant concrete, and this was used in the program. In effect, the hard rock prevented any movement of the casing adjacent to the rock, thus reducing the need for reinforcement. However, during excavation of the pit, blasting had cracked the rock near the pit walls, reducing the effective modulus of elasticity for a few meters around the pit periphery to less than the concrete modulus. When the program was re-run with a much lower modulus for the rock, tensile stresses in the casing wall and top slab adjacent to the end wall at unit #1, increased to such an extent that reinforcing would have to be increased threefold over that which had been installed. Some further work with the program showed that the cracking pattern could be duplicated - the error was in the rock modulus.

Repairs were expensive, consisting of a network of post - tensioned cables laced through the turbine floor slab, their optimum locations determined from the same computer program, a task which was complicated by the fact that jacking locations had to be accessible for testing. With the cables, and grouting of the pour joints, casing leakage ceased.

Lessons learned.

This case is difficult to diagnose. The design consultant had many years of experience in large hydro plant design, the utility's engineers were equally well qualified, and there was even a review board of international experts - but few had worked on a very large concrete semi - spiral casing powerplant, and those that had, were probably reluctant to question the results of a detailed and comprehensive finite element analysis, undertaken by an experienced and competent team. What was missing from the design team, was someone with enough rock mechanics experience to know that hard rock cracks for several meters from an excavation face, and also with some knowledge of computer programs to realize that a few "what if" changes to the assumptions could easily be undertaken, and a far different result perhaps obtained. With the top corner of the casing assumed to be restricted in movement by the unyielding granite, there was not even 45 degree corner steel - just where it was most needed to prevent crack propagation!.