Missing from the Checklist on the Safety of Nuclear Structures

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Recent news stories regarding the safety of nuclear reactors focus predominantly on meltdowns and exposed rods. Debates about the long-term safety of nuclear facilities emphasize human error and security breaches, sometimes alluding to insufficient controls on substandard construction, poor maintenance, and lax inspection. Nowhere, however, is the natural aging of the containment structure and other dependent structures addressed, nor does anyone discuss the effect of aging on capacity.

After 9/11, Hurricane Katrina, and the recent earthquake in Japan, engineers who design structures to withstand natural and manmade disasters modified their assumptions. Even non-engineers came to realize that human knowledge advances, and structural codes and designs evolve, one disaster at a time. Based on recent events, future designers of nuclear plants have no choice but to anticipate an increase in critical storms, the double whammy of earthquakes and tsunamis, where relevant, and the potential of airplane impact.

Nevertheless, these demands on a structure are only half the story – capacity is the other half. A basic tenet of structural safety is that capacity should always exceed demand. The problem is that natural aging decreases structural capacity, while demands on buildings, bridges, tunnels, and, of course, nuclear power plants, almost always increase over time. Assessing the current capacity of an aging structure to support growing demands is not an easy task, and the subject seldom receives the respect it deserves.

Unfortunately, the assertion that nuclear power plants are built to the strictest quality control standards is irrelevant. Stringent quality control during construction guarantees only that the structure's initial capacity approximates that intended by the original design. It does not prevent or forecast the nature of the inevitable degradation of structural capacity over time.

In fact, structures age much as people do. One would expect even the most robust newborn to have a few health issues at 40, and even more at 60. Moreover, they would be predictable only in the most general sense, because even a barrage of tests prognosticating good health does not preclude the subsequent occurrence of a sudden heart attack or the discovery of a malignant tumor. Likewise, engineers can say with relative certainty that a building will not retain its initial design capacity after 40 years, but current testing and inspection routines do not reveal the extent of the degradation with the same certainty. This applies whether the degradation occurs slowly, as corrosion, fatigue, wear-and-tear, or freeze- thaw cycles, or suddenly, due to an earthquake, hurricane, or terrorist attack. The good news is that, just as mapping and studying the human genome offers new hope for the prediction and prevention of disease, the emerging field of structural health promises to improve future estimates of structural degradation – welcome prospects for both human and structural health.

If we accept that structural aging of infrastructure is not necessarily visible to the naked eye, nor easily predictable, then meaningful assessment of the current state of degradation of infrastructure, including nuclear facilities, is the logical alternative. To be effective, however, it must be performed by knowledgeable, unbiased professionals who can apply the proper mix of state-of-the-art analysis and their own ingenuity, and who do not have a vested interest in the outcome.

The silver lining behind recent events in Japan may be that the new field of infrastructure structural health will be forced to expand rapidly, and that regulators may be motivated to adapt their protocols to include the insights the new field may provide. Certainly, our ability to assess the capacity of major suspension bridge cables has increased as aging bridges approach the century mark. Sophisticated sampling and analysis, better knowledge of how wires degrade over time, and noninvasive testing of wires inside cables now enable engineers to predict the rate of degradation and determine when cables require replacement. Knowing that 40 years is not too soon to begin assessing the structural health of bridge cables, however, does not guarantee that bridge owners will act on this knowledge.

Our hope is that the more educated people understand the subtleties of structural health, the more likely they are to push for more sophisticated and independent assessments that incorporate the effects of aging. Nuclear power plant owners should not shy away from these candid discussions, because they could increase public confidence in the decisions of regulators regarding nuclear power plant construction, decommissioning, and burial – decisions in which the public has a right to participate and that can have global repercussions.▪

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