TWI Report #6 – Identifying Day-One Defects

By: Steve Willie

TWI Report #1 claimed that all infrastructure defects and all infrastructure failures there have ever been (and ever will be) can be divided into the following three categories: old age, day-one defects, and subsequent damage. This report will address the day-one defects.

Day-one defects can be further divided into: (1) defective design, (2) defective materials, and (3) defective installation. We will review how these three types of defects often present themselves.

Although these are examples of day-one defects from the past, this is not really about the past. The past is important for the lessons it teaches, but the past is done. The fact is, these are examples of defects which are being installed in public infrastructure today, unless the public agency has an effective program to eliminate them from new construction before they are accepted.

Defective Design

Every type of infrastructure has many design standards associated with it. The engineer must correctly interpret and incorporate all of the applicable design standards while accounting for the relevant aspects of the physical sciences. <u>That is why engineers exist</u>. The failure to correctly apply the design standards will result in a defective design. Failure to account for physics can also result in a defective design. In most cases, failure to fully and correctly specify the applicable construction standards is also a defective design. The engineer is responsible for insuring that all the applicable requirements are included in all the documents sent to the fabricators, contractors, clients, or owners for final manufacturing or construction purposes.

One type of defective design is the selection of inappropriate construction materials. There is an excuse often mentioned that goes something like this: “back in those days, engineers did not have the advantage of all the space-age knowledge about materials we have today”.

However, this is not an acceptable reason for selecting the wrong materials for these two reasons: (1) Although today’s engineers may know more than they did in the past, they probably knew (or should have known) enough about the specific materials which they themselves selected; and (2) It is the engineer’s responsibility to fully account for the unknowns about the available materials.

Selection of the wrong materials can result in an unbalanced design, where part of the system has a significantly shorter lifespan than the rest.

For example, someone may look at rusty metal or crumbling concrete and attribute the degradation to old age. However, we should also consider the possibility that those materials (or their protection from corrosion) should never have been selected for that application in the first place. A significant amount of rust is not due to old age, but due to design errors (if there even was a design). Likewise, a significant amount of concrete corrosion could also have been avoided for the same reason. Remember this: every crack tells a story.

Here are some examples of corrosion caused by design defects from day-one:

- A lift station located in an area subjected to flooding, but with no protection from flooding. The flooding accelerated corrosion of

electrical equipment (and caused other problems).
- Hydrogen sulfide corrosion of concrete in a wastewater application which should have been predicted to be corrosive.
- Inappropriate specifications for surface preparation of a wastewater wet well which resulted in delamination of the coating, and degradation of the concrete behind the coating due to wastewater gases.
- Coatings specified for immersion applications which are not rated for full-time immersion.
- Using galvanizing to protect metals in a corrosive wastewater environment, or errors in specifying the galvanizing.
- Incorrectly specifying bolts or other fasteners.

It is also possible to simply make an engineering mistake. The thin gusset plates on the I-35W Bridge in Minneapolis are one example of this. The following are excerpts from the NTSB report on the failure:

- *"The gusset plates at the U10 nodes, where the collapse initiated, had inadequate capacity for the expected loads on the structure, even in the as-designed condition."*
- *"…the inadequate capacity of the U10 node gusset plates had to have been the result of an error on the part of the bridge design firm."*
- *"…the bridge design firm…failed to perform all necessary calculations for the main truss gusset plates".*
- *"The design review process used by the bridge design firm was inadequate…"*

If you read the reports about bridge defects and failures, you will usually find phrases such as "functionally obsolete" and "structurally deficient". Don't be mis-led by these phrases. They are often used as an excuse for incompetence, and will be the subject of a future TWI Report.

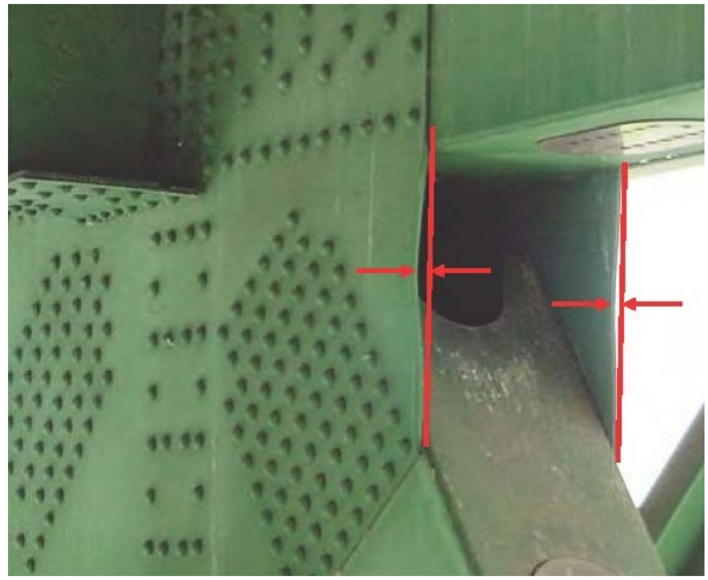

Photo 1: **The poster-child for defective design** - Gusset plates warped out-of-plane on the I-35W Bridge in Minneapolis directly causing the complete collapse and the deaths of 13 people. Defective design is a day-one defect.

There are so many different types of design defects that it is not practical to list them all. In addition, the categories tend to overlap. However, here is a partial list:

- A structure which is not sufficiently resistant to pressure, heat, vibration, abrasion, tension, compression, shear, bending, torque, cavitation, oxidation, stress cycles, creep, compression set, etc.
- Improper fit, wrong dimensions, insufficient clearance (interference), excessive clearance.
- Improper lubricant, lack of lubricant.
- Design-induced stress concentrations.
- Not correctly accounting for deflection, thermal expansion, friction losses, energy losses, acoustic resonance, hydraulic transients, and chemical incompatibility.
- Too difficult to maintain, too expensive to maintain, too expensive to construct or fabricate correctly, too expensive to insure,

lack of parts availability, long lead times to order, excessive energy costs to operate.

- Failure to meet the requirements of the owner, buyer, codes, environmental regulations, and regulatory agencies.
- Insufficient insulation, wrong type of insulation, excessive vapor transmission.
- Insufficient ventilation, inadequate mixing, excessive leakage, excessive permeability, and insufficient permeability.
- Inadequate factor-of-safety, pressure-relief, hydraulic capacity, cooling capacity, heat transfer, gas seals, electro-magnetic shielding, and instrumentation.

Defective Materials

All construction materials are manufactured, processed, selected, furnished, stored, and transported as required to meet specific written requirements for performance and function. If a material does not meet the applicable requirements, then those materials are defective from day-one.

Materials can be defective due to all kinds of accidental conditions. Perhaps somebody wanted to save some money, and honestly did not realize the damage they were doing. On the other hand, perhaps the problem was a deliberate attempt to sabotage quality to increase payouts or profits.

Have you ever heard about the large pipe manufacturer who fired their quality-control staff so they could get away with using cheaper PVC resins and running their pipe extruding machine faster than it was supposed to produce pipe? I will not mention their name because they will file a lawsuit against me, as they have done to others. Please type the following text into your web search and find out all about it: **"company which made defective PVC pipe"**.

Many miles of this pipe are already in the ground, like a time-bomb waiting to explode. Based on past behavior from public officials, the majority of future failures resulting from this defective pipe will be blamed on aging infrastructure.

Photo 2: **Split PVC C900** pipe caused by either defective pipe material or poor installation. Either one is a day-one defect.

Defective Installation

All construction materials must be installed in accordance with the construction plans and specifications, and the instructions from the manufacturer. If the materials are not installed using the correct process, then that results in a defective installation from day-one.

Here are some examples of defective installation:

- Pipe installed with insufficient bedding material or the wrong bedding material, which results in pipe damage during installation or pipe which settles later.

- Water services constructed by brazing copper service pipe into steel pipe threaded into a ductile iron saddle (can we assume that no engineer would have designed it this way?).
- Hammer taps to sewer mains for the installation of sewer services (was smashing the side of the pipe with a hammer ever a standard installation method?).
- Gaskets not installed correctly, which are not identified because the leakage test was not performed correctly.
- Bolts not tightened to meet the manufacturer's written installation instructions.

Photo 3: This is **another PCCP pipe failure** caused by either defective installation or defective manufacturing. Either way, it was defective from day-one.

This May Take A While

It may be true that these defects in design, materials, and installation will not result in failure for a long time. However, do not make the mistake of thinking that the cause of a failure is old age just because the infrastructure is old. In my thirty years of experience, many of the defects and failures that were blamed on old age are actually the result of day-one defects.

Signs of Distress in New Infrastructure are Not Acceptable

We work with imperfect information. We cannot know everything about the condition of our infrastructure or exactly how much longer it will last. However, we do know where the infrastructure is most likely to fail first. The location of the first failure is very likely to be a place which is already showing signs of distress right now. In other words, those cracks which you think are of little significance are actually quite significant. They probably show us where the first failure will eventually occur. Whether the failure takes 40 minutes or 40 years, that is a disaster for buried public infrastructure. Cracks or other signs of distress in new construction are not normal and are not acceptable. When it fails, don't blame it on aging infrastructure.

Your system for eliminating these infrastructure defects must be in place before they are created, or you will not get what you paid for.

ABOUT THE AUTHOR

Steve Willie is a Civil Engineer with over 30 years of experience designing, inspecting, and repairing public works infrastructure in the western USA, beginning at the City of Los Angeles Department of Transportation in 1987.

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