Role, Responsibility and Risk Considerations of the Engineer Regarding Sustainability

Dr. Patricia D. Galloway, PE, PMP
CEO, Pegasus Global Holdings, Inc.
Past President, ASCE

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Fundamental Concepts to Sustainability

- Environmental protection,
- Economic growth, and
- Social equity

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Economic Considerations

- What is the project cost that represents the best values from the perspective of achieving the project objectives?
- Have the life-cycle costs been analyzed to determine the total cost of project delivery over its expected life?
- Have environmental factors been included in the valuation of assets and services?

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Environmental Questions

- How does the project interact with the natural environment?
- Are there any concerns relative to the material or product proposed which may have potential future negative impacts on the project depending on the use application?

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Social Impacts

- How the person living next door is going to view the project?
- How can the project be best integrated into the community?
- Will the health, diversity and values of the community be maintained or enhanced for the benefit of future generations?
- Is the life expectancy of the selected materials and/or products the same relative to the social expectation of how long the project will function as designed?
- Is there a need for future inspections of any aspect of the project regarding it structural integrity to assure its sustainability over the expected design life?

Asset Management

- Asset management is a systematic process used to maintain, upgrade and operate physical assets cost effectively.
- Increasingly, cities and state governments are looking towards adopting asset management.
- While the need for the method of asset management has in the past been constrained by budgetary considerations, it now stands as a top priority.

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Asset Management

- Improving the durability of structures reduces the need for maintenance, repair, strengthening or replacement.
- The management of structures thus becomes more cost-effective in whole life terms.
- Structures last longer while meeting safety and functional requirements.

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Asset Management

- A key tenet of asset management is a process of early intervention taken before project failure that will minimize the cost stream.
- Projects will deteriorate over time and thus inspections, maintenance and operability are critical tasks that should be considered in infrastructure projects today.
- Asset management calls for a comprehensive assessment of all costs: design, construction, operations; and maintenance-the Life Cycle Cost Analysis.

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The Engineer's Role

- The Order of the Engineer and Professional Society Codes of Ethics and State Licensing Boards define the Engineer's role and responsibility
- The role is to design a project that meets the desired purpose, is constructible, and designed so that the user and public health safety and welfare are protected
- Today the role and responsibility goes beyond protecting today's public, but also to the protection of future generations and the environment
- Public works projects are constructed for public welfare; thus consideration as to project long term impact to society and ultimate client objectives play an important part
- Ignoring your role including sustainability issues could lead being found not to have followed a Standard of Care
- The Engineer can be held liable and even negligent

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Engineers Are Bound Ethically and Legally

- Order of the Engineer
- ASCE Code of Ethics
- Individual State Licensing Administrative Codes of Law

Order of the Engineer

- AS AN ENGINEER,
- I PLEDGE TO PRACTICE INTEGRITY AND FAIR DEALING,
- TOLERANCE AND RESPECT,
- AND TO UPHOLD DEVOTION
- TO THE STANDARDS AND THE DIGNITY OF MY PROFESSION,
- CONSCIOUS ALWAYS
- THAT MY SKILL CARRIES WITH IT
- THE OBLIGATION TO SERVE HUMANITY
- BY MAKING THE BEST USE OF EARTH'S PRECIOUS WEALTH.

- AS AN ENGINEER,
- I SHALL PARTICIPATE IN NONE BUT HONEST ENTERPRISES.
- WHEN NEEDED,
- MY SKILL AND KNOWLEDGE
- SHALL BE GIVEN WITHOUT RESERVATION
- FOR THE PUBLIC GOOD.
- IN THE PERFORMANCE OF DUTY
- AND IN FIDELITY TO MY PROFESSION,
- I SHALL GIVE THE UTMOST.

ASCE Code of Ethics

Fundamental Canon 1.0

- "Engineers shall hold paramount the safety, health and welfare of the public….
    - a. Engineers shall recognize that the lives, safety, health and welfare of the general public are dependent upon engineering judgment, decisions and practices incorporated into structures, machines, products, processes and duties.
    - b. Engineers shall approve or seal only those design documents reviewed or prepared by them, which are determined to be safe for public health and welfare in conformity with accepted engineering standard."

Florida Engineer's Act

- 471.005 (7) defines engineering "…design of engineering works and systems…and the inspection of construction for the purpose of determining in general if the work is proceeding in compliance with drawings and specifications…insofar as they involve safeguarding life, health, or property."
- 471.033 notes disciplinary proceedings if "…Engineer is…negligence, incompetent in the practice of engineering."

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Why Do Some Engineers Find Themselves in Trouble?

- Failure to fully understand the risks of decisions made
- Failure to understand and/or perform life-cycle cost analysis
- Failure to recognize and understand the differences in material or product selection
- Assumption that certain materials and/or products are merely a substitute
- Relying on “the computer is right”, standard designs and/or manufacturer literature vs. determining what is in the public domain
- Failing to meet a Standard of Care
- Assuming professional liability insurance will protect

The Standard of Care

- Standard jury instructions of standard of care:
  - **"In performing professional services for a client, defendant has the duty to have that degree of learning and skill ordinarily possessed by reputable engineers practicing in the same or a similar locale and under similar circumstances"**
  - **"It is his or her further duty to use care and skill ordinarily used in like cases by reputable members of his or her profession practicing in the same or similar locality under similar circumstances, and to use reasonable diligence and his or her best judgment in the exercise of his or her professional skills and in the applicability of his or her learning in an effect to accomplish the purpose for which he or she was employed."**
  - **"A Failure to Perform Any Such Duty is Negligence"**

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Negligence

- The failure to use such care as a reasonably prudent and careful person would use under similar circumstances
- Doctrine of negligence rests on the duty of the engineer to exercise due care in his/her conduct towards others from which injury may result

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Elements of Negligence

- Injury (damage)
  - To a party
  - That is reasonably foreseeable
  - And where there was a duty owed to the injured party

Judge Commentary in Actual Case

- *The parties dispute whether the defendants' negligence was a cause of the landowners' damages. The engineering firm hired by the City to investigate the failed drainage project concluded that the pipeline failure stemmed from design and material defects along with failure to test the materials.*
- *The defendants in this case undertook to control the lake's water level. The landowners maintain that if the defendants had exercised ordinary care in the design and testing of the pipeline, then the water level would have receded. They assert that the defendants' negligence thus caused the lake level to rise which, in turn, caused the damage to their property. The defendants dispute the allegations of negligence and assert that the facts reveal the exercise of ordinary care.*

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Ex.-Engineer's Responsibilities in Pipe Selection

- Pipe essential part of any project when it comes to drainage or transporting sewage away from or transporting water to people,
- Type of pipe products available varies significantly from RCP-concrete, corrugated metal, ductile iron and HDPE or PVC (plastic flexible) pipe.
- Regardless of the complexity, the decision made by the engineer regarding the pipe product selection can have a major impact to the performance or sustainability of the project over its expected design life.

Pipe- "Material Substitute"?

- A "client" may look at different piping products as "material substitutes" without regard for the use or application.
- Engineers often chose products due to specific client requests due to misconception that an "or-equal" clause is applicable no matter what pipe product is selected.
- Partial facts can lead to dangerous risks
  - price may lead to a false impressions that because the pipe requested is less expensive than its alternatives, the overall project may be less.
  - this is not the case and by making such an assumption adds an unnecessary risk
- In today's projects where sustainability must be taken into consideration, as required by engineering society codes of ethics some Professional Engineering Practice Acts, engineers cannot ignore that a client's request may not be appropriate or in accordance with the overall engineering practice to which an engineer is bound.

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The Engineer's Responsibility in Specifying Pipe

- Know the differences between flexible, metal and concrete pipe
- Determine who the manufacturers are
- Read and understand the manufacturer literature-distinguish ad "hype" from the actual manufacturer facts on their product
- Recognize that different pipe material requires different design requirements
- Understand the applicable standards, such as ASTM and AASHTO
- Recognize that the installation of flexible pipe is an engineered installation and that the Engineer MUST take an active role in both design and construction
- Inspection required post project completion
- Analyze the life cycle costs and risks associated with the pipe product chosen

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Differences Between Flexible and Concrete Pipe

- **Rigid**
  - **Load bearing structure**
  - **Load transfer down**
  - **Structure designed , built and tested is the pipe**
  - **Structure arrives on the truck**
  - **Not very soil structure dependent**
  - **Trenches have little effect on structural capacity of product**
- **Flexible**
  - **Load transfer to side support soil**
  - **Must deflect to function**
  - **Prime structure is soil**
  - **Soil dependent**
  - **Structure built and tested in the field**
  - **Designers must calculate the width of the trench required to provide sufficient structural strength for the system. This determination should be made by a soils expert**

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Standard Specifications for RCP

- ASTM C 76 Standard Specifications for Reinforced Concrete Culvert, Storm
- Drain and Sewer Pipe
- ASTM C 506 Standard Specification for Reinforced Concrete Arch Culvert,
- Storm Drain, and Sewer Pipe
- ASTM C 507 Standard Specification for Reinforced Concrete Elliptical
- Culvert, Storm Drain, and Sewer Pipe
- ASTM C 655 Reinforced Concrete D-Load Culvert, Storm Drain and Sewer
- Pipe
- ASTM C1417 Standard Specification for Manufacture of Reinforced Concrete
- Sewer, Storm Drain, and Culvert Pipe for Direct Design

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Sample Design Spec for RCP

1.04 Design

- A. Reinforced Concrete pipe shall be manufactured in accordance with ASTM C76, ASTM C 655, ASTM C 506, and ASTM C 507 and designed using the indirect method shown in the American Concrete Pipe Association Design Data 40. As an alternate to the indirect design methods described in Design Page 2 Data 40, reinforced concrete pipe is permitted to be manufactured in accordance with ASTM C 1417, and designed using direct design procedures per ASCE 15-98 Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations (SIDD). For pipe installed below the water table, an analysis shall be required, checking for possible flotation.]

2.01 Acceptance Testing

- A. Reinforced concrete pipe to be installed under this contract shall be inspected and tested at the place of manufacture as required by the Standard Specifications to which the material is manufactured. The Engineer or his representative shall be informed prior to any testing and may be present for or have a representative witness any and all testing. The Engineer will be provided copies of all test reports.

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The Standard Specifications for Plastic Pipe

- AASHTO M252-spec for CPP 3”-10”
- AASHTO M294-spec for CPP 12”-60”
- AASHTO Section 18: soil-thermoplastic pipe interaction system
- AASHTO Section 12: buried structures and tunnel liners
- AASHTO Section 30: thermoplastic pipe
- ASTM D2321: Standard practice for underground installation of thermoplastic pipe for sewers
- ASTM D3212: Standard spec for joints for drains and sewer plastic piping
- ASTM D3350: Standard spec for polyethylene pipe and fitting material
- ASTM F477: Standard spec for elastomeric seals (gaskets) for joint plastic pipe

ASTM D 2321-04

- "*For pipe larger than 12 inches (300 mm), the engineer should establish the minimum embedment width based on an evaluation of parameters such as pipe stiffness, embedment stiffness, native or in-situ soil, and magnitude of construction and service loads*."

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ASTM 2321-05

- ASTM 2321-05 states:

"*it is incumbent upon the product manufacturer, specifier, or project engineer to verify and assure that the pipe specified for its intended application, when installed according to procedures outlined in this practice will provide a long term satisfactory performance*."

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ASTM D 2321-05

- “*X1.1: Those concerned with the service performance of a buried flexible pipe should understand factors that can affect this performance. Accordingly, key consideration in the design and execution of a satisfactory installation of buried flexible thermoplastic pipe that provided a basis for the development of this practice are given in this Appendix* ”

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ASTM 2321-05

- *X1.2: General- Subsurface conditions should be adequately investigated prior to construction in accordance with Practice D 420, as a basis for establishing requirements for foundation, embedment and backfill materials and construction method. The type of pipe selected should be suited for the job conditions*

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ASTM-2321-05

- ***X1.3: Load/Deflection Performance-The thermoplastic pipes considered in this practice are classified as flexible conduits since in carrying loads they deform (deflect) to develop support from the surrounding embedment. This interaction of the pipe and the soil provides a pipe-soil structure capable of supporting earth fills and surface live loads of considerable magnitude. The design, specification and construction of the buried flexible pipe system should recognize that embedment materials must be selected, placed, and compacted so that pipe and soil act in concert to carry the applied loads without excessive strain from deflections or localized wall distortions***

ASTM-2321-05

- *X1.4.1: Construction deflections are induced during the process of installing and embedding flexible pipe, even before significant earth and surface loads are applied. The magnitude of the construction deflections depends on several factors as the method and extent of compaction of the embedment materials, type of embedment, water conditions in the trench, pipe stiffness, uniformity of embedment support, pipe out-of-roundness, and installation workmanship in general. These deflections may exceed the subsequent load-induced deflections*

ASTM 2321-05

- *X1.10: Engineer responsible to see proper trench width specified and consider all aspects of pipe installation, pipe thickness, embedment stiffness*

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ASTM 2321-05

- *X1.12 Other Design and Construction ….other sources of loads on buried pipe are…rising and falling of the ground water table, hydrostatic pressure due to ground water and localized differential settlement loads occurring next to structures such as manholes and foundations….*

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ASTM 2321-05

- *X1.13: Deflection Testing: To ensure specified deflection limits are not exceeded, the engineer may require deflection testing of the pipe using specified measuring devices. To allow for stabilization of the pipe soil system, deflection tests should be performed at least 30 days after installation…*

ASTM D 2321-05

- **Recommendations for incorporation into contract documents (for flexible pipe)**
  - **Further restrictions on uses of classes of embedment and backfill materials**
  - **Specific granulation of embedment materials for resistance to migration**
  - **Maximum particle size**
  - **Restrictions on mode of dewatering, design of under drains**
  - **Minimum trench width**
  - **Restrictions or details for support of trench wall**
  - **Specific restrictions on methods of compaction**
  - **Minimum embedment density and specific density requirements for backfill**
  - **Minimum cover**
  - **Detailed requirements for manhole connections**
  - **Requirements on methods of testing compaction and leakage**
  - **Requirements on deflection and deflection measurements, including method and time of testing**

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AASHTO Bridge Committee-Technical Committee T-4 Construction/T-13 Culverts-Revised 6/28/05

- Added inspection of thermoplastic pipe
- Working drawings-added substantiating calculations
- Drawings are to be approved by the Engineer
- Inspection for proper installation for proper performance
- Final inspection to evaluate long-term performance-conducted no sooner than 30 days after completion, installation and final fill
- Pipe should be evaluated to determine whether internal diameter of barrel has reduced more than 5 percent when measured not less than 30 days following completion of installation.
- Pipe checked for deflection using mandrel-shall be sized and inspected by Engineer prior to testing.

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What Authorities Have Researched and Found

- **Princeton University-July 06**
  - **-HDPE pipe material releases volatile organic compounds into water shown to be toxic to aquatic animals and potential humans having a significant impact on 100-year life.**
- **KYDOT-2005-7 HDPE sites-age: 2-15 yrs**
  - **Significant change in deflection since testing at completion. Most > 10%: Evident that several pipes continue to deflect after installation**
  - **Radial cracking, invert and crown flattening, racking and sagging observed: Evident that radial cracking occurs after installation**
  - **Specifications should ensure correct bedding and backfill requirements, proper densities and proper compaction efforts are adhered as outlined in ASTM D2321 and AASHTO Section 30**
  - **Additional laser testing recommended for long-term performance analysis**
- **TRB-Study of Culvert Failures-11/03**
  - **Service Life: for a major infrastructure project, designers should use a minimum project service life of 100 years**
  - **Plastics: Performance history limited. A designer should not expect a product service life of greater than 50 years.**

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Ductile Iron Pipe Research Association-2000

- ***Due to the inherent weaknesses in HDPE pipe, bedding conditions are much more critical than with Ductile Iron pipe. Proper bedding is required to control deflection, which is the single criterion in design of HDPE pipe for external loads. Standards dealing with recommended installation practices for plastic piping suggest that the pipe be surrounded by a soil with a minimum particle size, which is dependent on the pipe diameter, so that the soil can be sufficiently compacted to develop uniform lateral passive soil forces. The soil also must be free of organic matter. The trench bottom must be smooth and free from large stones, large dirt clods, and any frozen materials, as these objects could cause a reduction in strength due to scratches or abrasions. Such special bedding requirements are not practical or actually realized in many areas.***

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Final Report 621: HDPE-Arizona DOT survey, November 2006

- Alabama-no HDPE pipe over 48” as storm sewers and side drains and no HDPE pipe as cross drains under interstate highways.
- Alaska-no HDPE pipe over 48”.
- Arkansas-no HDPE pipe under interstate highways.
- California- HDPE pipe over 48” requires slurry cement backfills materials.
- Delaware -no HDPE pipe over 48”.
- The District of Columbia-no HDPE pipe.
- Delaware -no HDPE pipe over 48”.
- The District of Columbia-no HDPE pipe.
- Georgia-no HDPE pipe over 36” and no HDPE 60” pipe or under interstate highways.

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Final Report 621: HDPE-Arizona DOT survey, November 2006

- Delaware -no HDPE pipe over 48”.
- The District of Columbia-no HDPE pipe.
- Georgia-no HDPE pipe over 36” and no HDPE 60” pipe or under interstate highways.
- Iowa-no HDPE pipe in their primary highway system.
- Idaho-no HDPE pipe over 48” and not under Interstate Highways.
- Illinois-no HDPE pipe over 36” and their use is limited to culvert entrance and highways less than 3000 ADT.
- Iowa-no HDPE pipe over 48” and cross drain only for highways with less than 3000ADT.
- Kentucky-no HDPE pipe for its National Highway System (NHS) and does not allow HDPE pipe over 48”.
- Louisiana- HDPE pipe 48” or less is used and only under highways with less than 3000ADT and only on 2-lane connectors and local roads with 50-year design lives.

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Final Report 621: HDPE-Arizona DOT survey, November 2006

- Maine-HDPE pipe under highways on a case to case basis.
- Massachusetts-no HDPE under interstate highways and uses sizes up to 36”.
- Michigan- only uses HDPE pipe 36” or less.
- Minnesota only uses HDPE pipe up to 36”.
- Mississippi only uses 36” or less and is only allowed for side drains and for crossing roads with low volume less than 200 ADT.
- Montana only allows use of 18” HDPE pipe as an option of unpaved road applications and while experimenting with sizes of up to 48”, does not allow any HDPE pipe under interstate highways.
- Nebraska only uses HDPE pipe up to 36”.
- New Hampshire only allows HDPE pipe up to 36” and under pavement for low volume roads.

Final Report 621: HDPE-Arizona DOT survey, November 2006

- North Carolina uses HDPE pipe up to 48" but does not allow under interstate highways.
- Oklahoma rarely uses HDPE pipe, but when allowed, flowable fill is required as a backfill material.
- Pennsylvania-no HDPE pipe in projects with a service life of 100 years.
- Rhode Island- uses HDPE pipe 12-24" and larger sizes up to 48" but only where there is no live load.
- South Dakota-no HDPE pipe under State of Federal Highways.
- Tennessee uses HDPE pipe up to 48" but allows cross drains only for roads less that 1000 ADT.
- Texas does not allow the use of HDPE pipe larger than 48".
- Vermont and Virginia use HDPE pipe up to 48".
- Wisconsin uses HDPE pipe up to 36".
- Wyoming has not adopted a standard o n the use of HDPE pipe.

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Connecticut DOT

- **Connecticut does not use HDPE over 48" and does not allow HDPE pipe under highways. Connecticut's standard specification notes:**

"Designers must recognize that a buried plastic pipe is a composite structure made up of a plastic ring and the soil envelope, and that both materials play a vital role. In contrast, a buried reinforced concrete element is less influenced by the soil envelope….When specifying HDPE pipe, designers must consider loads from construction vehicles as well as those experienced during construction staging operations."

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Life-Cycle Costing

- **Life-cycle costing should be an integral part of the design process.**
- **While particular products may be less expensive relative to the product itself, the cost of the design process, the inspections during construction, and the operations and/or maintenance to be performed post construction must be applied in consideration of that product choice as these activities can significantly alter the overall life-cycle cost.**
- **Inspections may not be as soon or as frequent for one material as for another-e.g. concrete pipe as required for flexible pipe.**
- **Longevity depending on the application may be a consideration impacting future repair or replacement costs.**

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Life Cycle Cost/Performance Considerations

- **Inspection has become a critical component of asset management.**
- **In the example of selecting flexible pipe over other pipe alternatives, deflection is important to achieve its function.**
- **It has also been shown and so noted in US standards on flexible pipe, that deflections greater than 5% can constitute failure.**
- **Thus, the requirement for flexible pipe as noted in US standards such a ASTM and AASHTO for inspections to be performed no less than 30 days after installation become critical in the expectations of the future performance of the pipe product.**

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Prudent Risk Analysis as per Crumpler Plastic Pipe

- "When an engineer analyzes a storm water drain site there are numerous and complex factors to consider before selecting a pipe material or materials from the many pipe materials available today. Phase I of the selection-elimination process would be to determine the size of pipe or pipe needed to carry the 20-50-100 year projected storm flow of a particular site….

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Prudent Risk Analysis cont.

- …the Phase II step would be to perform a Life-Cycle-Economic Cost Analysis. The engineer would consider the chemical characteristics of the liquid flow, sediment load in the flow and the soil properties along the drain feed and main lines….The engineer is looking for Durability.
- ….Phase III is the selection-elimination process. Risk Analysis is the quantification of the exposure, vulnerability and probability. It involves the evaluation of alternative means to reduce risk and the determination of acceptable levels of risk.

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Environmental Considerations

- If proper design or installation is not performed failures may result causing property damage.
- If these events occur, then there are far greater consequences on communities. Thus, the "social impact" becomes a condition in the design process.

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Societal Impacts

- In today's environment, the client is looking to the engineer to provide solutions that will not only be in the best interest of "today" but will serve as a solution for "tomorrow" and the "future".
- Sustainability considerations, life-cycle costing and asset management considerations are all areas that an engineer should be addressing along with the risks that may arise based on decisions to be made in these considerations which in turn may fall to an expected standard of care.
- The design process must consider the knowledge of a particular product performance as obtained in the public domain
  - assumptions made in the design process will be used in standard of care allegations

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Conclusions

- Identification of risks and consideration of actions to be taken should risks occur are becoming the expectation and not a concept of the future.
- If sustainability consists of employing concepts of life-cycle costing, asset management, and future impacts to society, what happens if the engineer fails to take into consideration such steps in its design considerations?
- One such liability could be an assertion to follow a standard of care.
- This assertion may further be compounded if the engineer failed to fully evaluate a product relative to information that was available to him or her relative to the design, standards and applicability.

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Conclusions

- A failure to meet a standard of care may be deemed to be negligent. Negligence is not typically covered by professional liability insurance policies, thus the potential consequences to the engineer could be quite high.
- Legal aspects and court room and arbitration testimony foreign to most engineers, yet this lack of understanding is what is now coming back to haunt the engineer.

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Conclusions-in Pipe Example

- **Concrete, metal and flexible pipe are not the same and not alternates to each other**
- **Soils are different at every jobsite**
- **If specifying flexible pipe, Engineer must be at jobsite to oversee installation as the structure is designed and tested in the field**
- **In flexible pipe, only way to determine if a structure has been built according to your specs is through testing of the entire system**
  - **If a deflection of > 5% Fails**
  - **Require no sooner than 30 days after backfilling and again prior to the surrender of the performance bond (12 months)**

Conclusions

- Engineers design, specify, require and ENFORCE
- The Engineer has a sworn duty to protect the public health safety and welfare
- Forgetting any of the above results in the Engineers assuming the role of the Responsible Party with all the risk, liability and consequences thereto.

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