Testing and Evaluation

- All engineering project should be tested and evaluated, determining the project’s:
  - Effectiveness,
  - Reliability,
  - Safety, and
  - Performance compared to the objectives, criteria and specifications.

Testing and Evaluation

- Testing and evaluation maybe also be incorporated throughout all aspects of the design process.
- Component maybe tested separately.
- Complete project must also be tested, at least to determine whether there are unforeseen interactions between components.

Testing and Evaluation

- Testing methodology often revolves around the project costs.
- An expensive, one-of-a-kind project will often undergo limited non-destructive tests, like progressive loading.
- Failure is determined from physical and/or mathematical modeling and the non-destructive test results.

Testing and Evaluation

- Expensive, one-of-a-kind projects are designed more conservatively, because testing and evaluation will have more uncertainty associated with the results.

Testing and Evaluation

- Inexpensive, mass produced projects will often undergo destructive tests, like failure loading.
- Failure is determined directly from destructive test results.
- Uncertainty in results can be understood by increased testing.
**Testing and Evaluation**

- Inexpensive, mass produced projects can be designed less conservatively, because new testing and evaluation results can be incorporated into future production runs.

**Model Testing**

- Models of the product are tested without any serious expenditure of funds.
- Mathematical models, computer models and electrical or hydraulic models can be developed and tested on routinely available, relatively standardized systems.
- Do inputs and virtual responses accurately reflect the real response?
- Physical (scale) models can be used to estimate responses that can describe the product.
- A limitation of physical models is that response may not be linearly related to scale, and expertise in dimensional analysis maybe required.

**Prototype Testing**

- A full scale prototype maybe developed and tested, prior to full production.
- Works in the construction world, only when there is a prior build project that is similar.
- Prototypes are typically tested in both controlled conditions and then field conditions.

**Testing and Evaluation**

- There are three primary levels of testing that each product may involve:
  - Model testing,
  - Prototype (full scale) testing, and
  - Product testing.

- Prototypes copies can be loaned to users so that its performance can be evaluated, generating results from the most realistic operating conditions possible.
Product Testing

- Once the project is complete, product testing can be performed.
- Again the degree of testing is based on the economics.
- Samples are taken to ensure that a product meets required criteria and to ensure quality control through the production.

Testing and Evaluation

- All product testing must have a clear purpose and protocol in order to be valid.
- Test design includes knowledge of anticipated modes of failure, development of testing techniques, statistical procedures and specifications of acceptable and unacceptable performance.

Testing and Evaluation

1. What is being tested?
2. Why is it being tested?
3. What is the hypothetical outcome of the test?
4. What biases are inherent in the test procedure?
5. Are there governing standards for this test and test outcomes?

Statistics

- Statistical analysis of test results should show the variability of the results and the deviation of the results from the specifications.
- Reasons for the variability and deviation are usually not inherent in the statistical analysis, but must be inferred in order that corrections can be made.

Statistics

- The statistical analysis is almost useless if the specifications and hypotheses are not developed before the test.
- “Whatever happens, happens” is not a specification.

Quality Control

- Quality control is an ongoing form of testing during the production run to assure that the quality of the product remains high.
- There may be in-process inspections so that errors can be corrected early.
- End-of-the-line inspections of a finished product can accept, reject or re-route the product for repairs.
TQM (Total Quality Management), a concept in which a design/production team is responsible for grading their own work. TQM was used extensively as a quality control model in the 1980s and 90s. TQM shifts the responsibility for quality to the small teams, and it is most popular with managers.

Six sigma – six standard deviations away from the mean, which represents 99.9999999% reliability. This allows only 1 error in 1 billion. This may seem high but if 1 processor contains just 1 million transistors, and just one transistor error can cause a processor failure, 6 sigma reliability would result 1 in 1,000 bad chips.