Quality Assurance for Structural Engineering Firms

Clifford Schwinger, PE
HARMANGROUP
structural engineering • parking planning and design • construction engineering
Philadelphia • New York
WWW.HARMANGROUP.COM
eschwinger@harmangroup.com

October 11, 2017 DVASE Breakfast Presentation

Learning Objectives

1. Discuss the importance of structural engineering Quality Assurance
2. Review the components of a Quality Assurance program
3. Review tips for performing QA reviews

What is a Structural Engineering QA program?

A system of procedures and processes used to facilitate efficient production of high-quality structural design and high-quality contract documents for that design.

Why is a QA program important?

- The pressure to get more done, faster, and better for less (no “simmer time”)
- Complex codes and design standards
- Complex analysis and design software – and blind reliance (by some) on that software
- Building Information Modeling
- Less experienced engineers taking on more responsibility earlier in their careers
- The lost art of structural drafting
- Communication challenges

Why is QA important?

Figure 18-2 Comparison of as-constructed and as-designed hammer rod details.

Why is QA important?
### Advantages of a QA program
- Better design
- Better drawings & models
- More efficient design process
- Better working environment for young engineers – and everyone else
- Fewer mistakes
- Fewer RFI’s & change orders
- Increased profit
- Enhanced reputation

### The QA program manages:
- Design standards
- Drafting, detailing, and modeling standards
- Training
- Documentation of design
- Ongoing quality assurance reviews

### The QA program 30 years ago
- QA manager available to answer questions
- A single QA review at the end of design

### QA today
- Formal processes and procedures
- “Ongoing Quality Assurance”

### Who is responsible for Quality Assurance?
- Everyone
- Teamwork and communication
- Everyone should be able to contribute to the QA program
- Everyone must “buy in” to the program
- Willingness to accept constructive criticism

“I don’t want anyone looking at my design.”
The Quality Assurance Program

Components of a QA Program

1. QA manager
2. Training
3. Design standards
4. CAD & BIM standards – focus on drawing quality
5. Project Delivery System
6. Knowledge Base
7. Multiple QA reviews ("Ongoing QA")

1. QA Manager: Requirements

- 15 years experience (minimum)
- Knows the codes and design standards
- Detail oriented
- Problem solver
- A (balanced) nit-picker
- Flexible (willing to consider options)
- Practical (not overly theoretical)
- Enjoys working with others
- Doesn’t shy from confrontation
1. QA Manager: Responsibilities

- Establish / maintain office design standards
- Answer technical questions
- Train staff
- Review framing plans & details before going to CAD
- Maintain involvement & familiarity on projects
- Perform multiple QA reviews throughout design

2. Training

You can’t grow a tomato in a week.

2. Training

- Formal training seminars on topics required to for engineers the to become more productive.
- “Boot camp” training for new hires
- Lunch and learn seminars for everyone
- TEK notes
- Interaction between new engineers and senior engineers

2. Training: New Engineers

Topics:
- Shop drawing review
- How buildings go together (design, details, documentation of the design and details)
- Structural “drafting” and detailing
- AISC 360
- Structural steel connection design
- Constructability / connection “designability”
- ACI 318

2. Training: Lunchtime Seminars

Topics:
- IBC & ASCE 7
- Lateral analysis
- Validating computer analysis
- Strut and tie design
- Cold-formed steel design
- Wood design
- Concrete mix design
- Braced frame connections
- Webinars, manufacturer lunch and learns
- And more....

2. Training: TEK Notes
3. Design Standards

- In-house design guides
- Office procedures (modeling, drafting, LRFD vs ASD, etc.)
- Checklists

Must be office-wide consistency.

4. CAD & BIM Standards / Drawing Quality

- CAD / BIM / drafting / detailing procedures
- Training on structural "drafting" for engineers
- Training on structural drafting for CAD personnel
- Typical details
- "Go-by" drawings
- BIM procedures and standards
- Pre-detailing CAD sign-off

4. Drawing Quality

High-quality drawing presentation is essential

- It is easy to spot errors on good drawings
- Bad drawings can hide errors
- Bad drawings can be misunderstood
- Good drawings enhance safety
- Good drawings reduce confusion, RFI's and change orders

Establish written standards for drafting

Figure 4.2 Comparison of interrupted and continuous hanger rod details.

4. Drawing Quality

Produce "Go-by" drawings

25

26

27

28

29

30
4. Drawing Quality (1896)


5. Project Delivery System

Checklists and procedures for:
- Project startup
- Schematic design
- Design development
- Contract documents
- Construction Administration

The PDS is:
- A road map
- Eliminates re-invention of the wheel
- Fosters uniformity and consistency

6. Knowledge Base

- Server-based database of structural engineering knowledge
- Similar to Wikipedia
- Contains checklists, design guides, seminar notes, TEK notes, etc.

7. QA reviews

- Ongoing QA (multiple QA reviews)
- QA manager maintains familiarity with all projects as they progress through design
- Ongoing QA will catch problems early (when they are easy to fix).
- Ongoing QA improves productivity

The Quality Assurance Review
(the “in-house” peer review)
Quality Assurance Reviews

In-house reviews conducted to verify that design and documentation is in conformance with procedures, practices and standards mandated by the QA program.

This discussion is applicable to all engineers – not just those performing QA reviews. All engineers are responsible for performing their own “self – QA review”*

*The “self-QA review” is not a substitute for an independent QA review by someone else.

Why a “self-QA” review is not enough

Black holes stand at the very edge of scientific theory. Most scientists believe they exist, although many of their theories break down under the extreme conditions within. But Professor Cornelius Van Bockstein of the University of Ushuaia says he knows what you would find inside, and challenges the traditional idea that gravity would cause you death by “spaghettification”.

Count the number of F’s in the text above.

Purpose of the QA Review

A second set of eyes will find:

- Mistakes
- Confusion
- Missing information
- Constructability problems

The QA review:

- Provides a level of redundancy to the design process
- Monitors the effectiveness of the QA program

Primary Goal of a QA Review

To verify that structures are properly designed

Look at:

- Big picture – load paths / framing efficiency
- Member sizes
- Critical connection details
- Constructability
- Glaring errors

Secondary Goal

To verify that drawings are complete, coordinated and correct. Look at the drawings through the eyes of the,

- Architect
- Contractor
- Steel fabricator
- Detailer
- Inspector
- Peer reviewer
- Building Official
- Detailer
- Young engineer reviewing shop drawings
- Lawyer

QA Review Checklist

1. Big picture
2. Load paths
3. Stability & redundancy
4. Framing sizes
5. Strength & stiffness
6. Validate analysis model
7. Connections
8. Details
9. Constructability
10. Look for mistakes
11. Design creep
12. Look for subtleties
13. Look at drawings through the eyes of others
14. Clarity & consistency (poor drafting)
15. Omissions
16. “Little” little things
17. “Big” little things
18. Coordination with others
19. Other things...
1. Look at the big picture

- Load paths
- Global stability issues (and subtleties)
- Local stability and bracing subtleties
- Connections
- Inefficient framing
- Design loads
- Problems with model (what did model miss?)

2. Verify Load Paths

- Any unrealistic load paths?
- Are all load paths complete and continuous?
- Any loads jumping in & out of braced frames, moment frames and shear walls?
- Problems related to “infinitely rigid” diaphragms?

2. Verify Load Paths

- Do the forces resolve?

2. Verify Load Paths

- Any questionable braced frame forces from computer analysis?

2. Verify Load Paths

- Did the computer analysis consider load path issues if the floor diaphragm is not connected to the braced frame? (Probably not?)
2. Verify Load Paths

Did the computer analysis consider drag strut forces?

3. Stability & Redundancy

- Are there enough braced frames, moment frames and shear walls?
- Are they properly sized and located?
- Are any columns braced in the computer model but not in reality?
- Is there sufficient redundancy?
- Any “Islands of instability”? 

4. Check framing (gravity & lateral)

Check:
- Typical framing to verify the analysis model
- Every major load-carrying member
- Wind and seismic loads
- Unique framing and loads that may not be in the computer model

Show reactions

- Showing reactions makes the QA review easier
- Load paths are easier to follow
- Mistakes are easier to find (modeling mistakes)
- Forces designer to think about the connections
- Reduces cost (allowing fabricator to detail connections for actual reactions).
**Things requiring special attention**

- Elevators
- Escalators
- Facades
- Davits
- Stairs
- Monumental stairs
- Hangers
- Theater rigging

- Folding partitions
- Special hang points
- Rooftop MEP loads
- Heavy hung piping
- Special loads on joists
- Horizontal loads from rigging
- Catwalks
- Unusual framing

**5. Strength and stiffness**

The model assumed a diaphragm with infinite strength and stiffness.

**6. Validate the analysis model**

Simple tools can provide important information.

Simple manual checks can validate complex structural analysis performed with computers.

Don’t get lost in the model.

Simple tools provide valuable information.

We see what we want to see.

The way we hope a structure works influences the way we model it - and the way we interpret the results.

Understand the software:

- What are the flaws and simplified assumptions made by the software programmers?
- What are the variables?
- What are the defaults?
- What are the prejudices (invalid assumptions) that we put into our models?
There is nothing inherent about finite element analysis modeling that makes it correct. View all models with suspicion. Never get complacent with the computer analysis.

What did the computer not check?
- Framing through steps in floor slabs
- “Infinitely rigid” diaphragm issues
- Incorrect assumptions made in model
- What was not checked? (wind shielding)
- Global stability (“islands of instability”)
- Load path subtleties (drag struts, girt loads)
- What is not in the model? (missing loads, etc.)
- What changed since the model was first created? (roof screens, slab openings, rooftop MEP units, steps in floor slabs, revised slab edge locations, etc.)
- Struts and strut load paths at each end of sloping columns

How are wind loads computed?

How are members designed?
- Compression: Were angles designed as concentrically loaded (Table 4-11), eccentrically loaded (Table 4-12) or per Section E5 “Single Angle Compression Members”?
- Tension: was shear lag factor, “U” considered?

Critical connections
- Unusual connections (slide bearings, etc.)
- Connections with complex geometry
- “Kinked Connections” – connections with jogs in the load path through the connection
- Hangers
- Truss connections, braced frame connections
- Connections with large reactions
- Are all connections “designable” (review even when delegating connection design)
- Look for problems due to revised framing configurations
8. Think through & document all of the details

How did you want that slide bearing to the existing column detailed?

Mindset to foster good design

- If you don’t understand the details, you can’t do good design.
- Think about the details first, then design
- Think about “connection designability” (even when delegating connection design)
- Provide connection concept details – even when delegating connection design. (Conceptual connection details are specifically required by the 2016 AISC Code of Standard Practice)

9. Constructability

Steel buildings:
- Will the pieces fit together?
- Are the connections designable?

Concrete buildings:
- Is the formwork economical and repetitive?
- Can the reinforcing steel be easily installed?
- Just because the computer analysis says the design works does not mean that it can be built – or even that it works.
9. Constructability

These connections are neither constructable nor designable.

10. Look for mistakes

- Wrong reactions
- Members too small
- Improper framing configurations
- Insufficient or missing reinforcing steel
- Punching shear problems
- Missing structural integrity reinforcing steel
- Missing sections and details
- Mistakes in sections and details
- Mistakes in computer model
- Invalid assumptions made in computer model
- Insufficient diaphragm strength/missing diaphragm connections

11. Design Creep

Small changes in slab edge locations can drastically affect punching shear capacity in flat plates.

Example: Slab opening added near column; girder shifted to avoid opening; girder now connecting to beam but beam and beam reaction not revised.

11. Design creep during construction

Missing reactions, design creep and a translation error can cause a structural failure.

Figure 10.1: Comparison of interrupted and continuous hung and details.
12. Look for subtleties

- Column splices at inappropriate locations (mid-height of 100’ unbraced height)
- Framing through steps in floor slabs
- Diaphragm issues
- Incorrect assumptions made in computer model
- Things not checked in the computer analysis
- Stability subtleties (“islands of instability”)
- Double-height columns taking wind load
- Load path subtleties (circular framing)

13. Look at the drawings through the eyes of others

- Look at the drawings from the perspective of someone who’s not an engineer
- Is everything shown that will allow contractor to build structure without having to guess or issue RFI’s?
- Is every foot of the building perimeter covered by a section?
- Is everything clearly indicated?
- Is bad drafting obscuring important information?
- Anything missing?
- Are all details provided?
- Any conflicting information?
- Can the drawings be interpreted by someone who’s not an engineer?
- Search drawings for potential change orders

14. Clarity & Consistency (Poor Drafting)

Sloppy drafting can cause structural failures
14. Clarity & Consistency (Poor Drafting)

- Look for conflicts between framing plans and sections/details.
- Inconsistencies with framing
  - Group similar beams
  - Consistency = simplicity = economy
- Drafting inconsistencies
- Are sections and details cut in a uniform manner?
- Are the details well thought out, arranged in an organized manner and well-drawn?

15. Look for Omissions

Look for the things that are not there.

Missing:
- Reactions
- Section/details
- Dimensions and elevations
- Sizes
- Reinforcing steel
- Beams
- Columns
- Expansion joints
- Slab openings
- Excessively long slab-on-metal-deck spans

16. Look for “little” little things

- Spelling mistakes
- Sections cut the wrong way
- Improper dimensioning
- Text over text / text over lines / lines over lines
- Improper text font, size, justification, etc.

17. Look for “BIG” little things

- Slab opening cuts off load path to column.
- Opening not shown on structural drawings.

18. Coordination with Others

- Dimensions and slab edges
- Facade sections, details and support requirements
- Column locations
- Slab openings
- Headroom clearances
- Slab elevations, slopes, depressions and steps
- Floor plans (verify design loads)
- Stairs, elevators, escalators
- Rooftop screen walls, MEP penthouse, parapets...
18. Coordination with Others

MEP Coordination
- Heavy piping & equipment loads
- Large ducts (headroom interference with framing)
- Beam web penetrations
- Slab embedded electrical conduit
- Below grade utilities

19. And many other things...
- Serviceability issues
- Foundations
- Wood framing
- Precast
- Window washing davits
- Roof screens
- Rooftop dunnage
- Facade connections
- Delegated design
- Elevators
- Escalators
- Stairs/monumental stairs
- Durability issues

Things to remember
- Never get complacent
- Ongoing QA
- Few things are binary in structural engineering
- Good communication is essential
- Load paths, stability, reactions
- Understand software limitations
- Look for what is not there
- Changes after design can cause problems
- Drawings and design must be complete
- Seemingly small things can cause big problems
- Think through the details while designing

Summary

QA program
1. QA manager
2. Training
3. Design standards
4. CAD/BIM Standards
5. Project Delivery System
6. Knowledge base
7. QA reviews / Ongoing QA

Teamwork, communication, and “Ongoing QA” are essential
Quality Assurance is everyone’s responsibility
Thank you
Questions?
Clifford Schwinger, PE

HARMAN GROUP
structural engineering • parking planning and design • construction engineering
Philadelphia • New York
WWW.HARMANGROUP.COM
cschwinger@harmangroup.com