NAC Executive Insights

Safety by Design Suggestions

Key Points

- Safety is best achieved by eliminating hazards, which should begin at the design stage.
- Expanding the basis of design to eliminate hazards and providing actionable suggestions to designers hold the promise of reducing hazards.
- Seven categories of suggestions regarding safety by design, encompassing 82 total suggestions, are identified in this Executive Insight.
- These suggestions represent a starting point, but much more is possible. Please submit to NAC your suggestions for improving safety by design.

Introduction

This Executive Insight builds on the NAC Executive Insight entitled "Safety through Design," which provides a top-level view on the importance of hazard elimination at a project's design stage and lays out a number of guiding precepts. It can be found on the NAC website.

In this Executive Insight, we present numerous safety by design suggestions, subdivided into seven categories. Readers are encouraged to submit additional suggestions to NAC for a future revision of this Insight.

The following 82 suggestions merely scratch the surface of what is possible. Project owners and design professionals should continue to focus on removing design hazards from both the construction and operation and maintenances (O&M) phases of a project.

Safety by Design Categories and Suggestions

1. **Site Layout – Implications of designs on safety during preparation of the site layout**

    1. Design site logistical flows to separate people, materials, and vehicles.
    2. Separate construction logistical flows (equipment, labor, and materials) from any existing plant flows.
    3. Incorporate adequate clearances required for construction equipment and selected construction means and methods.

4. Incorporate safety features that are required for demolition of existing assets.
5. Design to minimize exposure of workers to adjacent traffic and other hazards.
6. Design to avoid interferences between different construction elements during construction.
7. Minimize excavations.

2. General Considerations – Implications of designs on safety broadly applicable throughout the project.

1. Reduce the need for enabling and temporary works.
2. Design to incorporate temporary facilities into final structure.
3. Select safe-to-handle construction materials.
4. Provide comprehensive and understandable plans and instructions to enable safe use of designed access ways and systems.
5. Design effective noise barriers and acoustical treatments for walls and ceilings.
6. Use pre-finished materials in preference to on-site finishing.
7. Select low volatile organic compounds (VOC) paints or other finishes.
8. Use nonslip materials on floor surfaces exposed to weather or in dedicated wet areas.
9. Use durable materials not needing to be recoated or treated.
10. Using sub-floor heating on floor surfaces exposed to moisture from weather or tracked moisture.
11. Provide complete, high quality designs in order to minimize rework.
12. Eliminate sharp edges.
13. Reduce the weight of components to be moved frequently.
14. Minimize potential pinch points.
15. Design to facilitate emergency response in operations.
16. Reflect work platforms, equipment laydown, and pull areas in design.
17. Design for rapid replacement of routine maintenance items.
18. Minimize joints and bearings.
19. Actively consider the use of safety innovations including:
    a. Drones
    b. Virtual Reality
    c. Augmented Reality
    d. Hard Hats with the ability to Detect Carbon Monoxide
    e. Wearables
    f. Site Sensors

3. Structures Considerations – Implications of designs on safety with respect to the erection and maintenance of structures and structural considerations to minimize other safety risks.

1. Minimize temporary stairs and scaffolding by designing permanent stairways to be constructed early in the construction process.
2. Ensure construction drawings reflect design loads for different parts of the structure to avoid overloading during construction.

3. Design roof parapets to guardrail height to eliminate need for guardrails during construction and to provide added protection during O&M activities.
4. Integrate cleaning bays and gangways into the permanent structure for use during construction and maintenance.
5. Design safe access (stairways, fixed ladders, and platforms) and space to safely complete structure maintenance activities.
6. Design and position permanent anchorage and hoisting points into structures where maintenance will have to be completed at height.
7. Use durable materials to eliminate the need to recoat, treat, or frequently clean.
8. Design steel and concrete structures with provisions for fall protection barrier cables by designing holes in columns.
9. Select roofing systems that are less damaging to the environment and to workers health and safety.
10. Provide for use of continual support beams for beam-to-column double connections by adding a beam seat, an extra bolt hole, or another redundant connection point. This helps eliminate falls due to unexpected vibrations, misalignment, and unexpected construction loads.
11. Design column splices and connections at reasonable heights above the floor.
12. Select building materials, paints, and finishes that emit low levels of dangerous vapors.
13. Design access to structures based on their specific purpose, with appropriate features such as wide corridors or extra width doors.
14. Avoid creation of dirt traps requiring frequent maintenance, especially in difficult to access locations.
15. Design structures to isolate plant noise (not just vibration isolation).

4. Mechanical Suggestions – Implications of designs on safety related to construction and maintenance of various mechanical equipment and minimization of potential safety effects associated with them.

1. Reduce the need for manual tasks by designing spaces to facilitate the use of mechanical plant and tools.
2. Incorporate fixed access for major mechanical equipment for maintenance purposes (i.e., fixed stairs to a machine room).
3. Incorporate aids for lifting various mechanical and HVAC equipment during construction and O&M (lifting lugs for roof-top air conditioning plants).
4. Provide space within structures to safely install, operate, and maintain mechanical and HVAC equipment.

5. Design to physically or through dampening to isolate plant noise and vibration.
6. Specify plants with low noise emissions.
7. Design floor loadings to accommodate heavy temporary equipment and machinery used in the structure for installation or maintenance and replacement of mechanical plant and equipment.
8. Design mechanical plant and equipment to avoid dirt or moisture traps requiring excessive maintenance.
9. Provide adequate space for making connections (mechanical and electrical) to mechanical plant and equipment.
10. Provide adequate space for safely performing required welding operations. Ensure adjacent equipment is adequately protected or appropriately repositioned during all welding operations.
11. Design equipment layouts while taking into consideration proper maintenance and future replacement. Maintenance activities requiring safe clearances include pulling coils on major air handlers, rodding chiller tubes in a water-source cooling system, and changing out motors and filters.
12. Reduce fall risk by incorporating guardrails for maintenance activities performed near roof edges or in steeply sloped areas.
13. Incorporate provisions for placement of major equipment in or on a building. Pathways necessary for the equipment and workers for install and replace activities should be part of the design process and should be reflected in design documents.
14. Design beams to allow hoisting where needed.
15. Design for inserts (cast or attached to structure) to facilitate winching mechanical equipment and other possible loads.
16. Ensure existing mechanical and other utilities of a facility have been well identified and reflected in the drawings issued for construction.
17. Consider moving air conditioner plants to ground level while retaining ducts in the traditionally planned positions.

18. Evaluate use of lightweight ductwork (15 percent weight of traditional sheet metal ductwork) to allow handling without the need for mechanical lifting equipment.

5. Electrical Suggestions – Implications of designs on minimizing safety risks associated with electrical equipment and systems and how they may add to improved plant safety.

1. Provide clearance between construction equipment, buildings, and structures and existing overhead electric lines; detail burying, disconnecting, or re-routing of cables by design before construction begins.

2. Bury cable chases under main site roads required for commissioning and startup to eliminate conflicts between electrical and control homeruns and other site construction, commissioning, and startup activities.
3. Develop designs to isolate power until the later stages of construction.
4. Use LED lighting and other long-lived consumables to minimize the need to replace during construction and subsequent operations.
5. Provide sufficient lighting for construction and maintenance tasks to be performed in buildings and structures or regularly during times of the day or seasons of the year where ambient light levels are low.
6. Ensure adequate space for making final power and controls connections after equipment has been installed. Ensure adequate space during the O&M phase of the facility as well.
7. Ensure adequate access provisions exist for late installation of major equipment and for subsequent replacement during O&M. Considerations must include any equipment necessary for installation or removal work and the travel paths of this equipment. Examples include forklifts, mobile cranes, other vehicles, and overhead cranes (permanently or temporarily installed).
8. Ensure floor loads have considered any temporary equipment used in the installation or maintenance of major electrical equipment.
9. Indicate location and height/depth of all electric lines in the BIM model and drawings issued for construction to facilitate site safety procedures. The BIM model must include the thickness of fireproofing on steel members.
10. Position lighting for easier access/maintenance during construction and O&M.

6. Controls Suggestions – Implications of designs to ensure safe operation of the plant and its systems through a full range of potentially safety-impacting conditions.

1. Design to ensure control systems safely initialize in the intended state, safely and verifiably change modes and states, and prevent hazardous system mode combinations or transitions.
2. Design safety critical software to include only required and intended functionality.
3. Design systems in the event of unexpected loss or corruption of command link to transition to a predetermined and expected state and mode.
4. Design to provide for contingencies in the event of safety critical failures or emergencies.
5. Design to provide information, intelligence, and method of control to support safe operations.

7. Preassembly and Modularization Suggestions – Implications of design on the safe assembly and erection of plant components, systems, and structures.

1. Reduce exposure to fall from heights and being struck by falling objects by providing designs where assemblies, components, and structural elements can be completed at grade level.
2. Reduce exposure to falling objects by performing electrical and controls preassembly and module construction offsite.
3. Finish or partially finish components offsite to reduce exposure substances that may be hazardous to health, such as dusts, paints, and glues. Offsite assembly should be accomplished in a controlled, manufacturing environment.
4. Evaluate the following (as a minimum) for preassembly/modularization:
    a. Steel stairs, prefabricated concrete stairs
    b. Precast concrete walls and other components
    c. Equipment racks
    d. Piping systems
    e. Ductwork assemblies and glazed curtainwall
    f. Prefabricated specialized rooms such as sampling stations, clean rooms, and hospital rooms
    g. Prefabricated rooms with repetitive elements such as toilets or dorm rooms to substantially eliminate onsite construction,

reducing the time workers are exposed to potentially dangerous or unhealthy working conditions.

h. Buildings or major portions of industrial buildings lending themselves to complete or substantial modularization.

5. Ensure transportation and handing requirements of any modules have been provided for with adequate clearances to reduce installation safety risks (crane travel paths and heights; self-propelled modular transporter travel paths and turning radius).
6. Use preassembly to eliminate or minimize the need for entry into confined spaces.
7. Where practical, install windows in panels before panel placement to reduce the risks of falling objects.
8. Limit the size of prefabricated elements, including glass cladding, where access is restricted (site/plant access).

Conclusion

Safety begins at the design stage and this begins with a more comprehensive view of the basis of design. Readers are encouraged to examine the NAC Executive Insight "Business Basis of Design"). That particular Executive Insight seeks to focus designers on strategies to mitigate hazards in both construction and operations and maintenance.

About the Author

Bob Prieto was elected to the National Academy of Construction in 2011. He is a senior executive who is effective in shaping and executing business strategy and a recognized leader within the infrastructure, engineering, and construction industries.