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ABSTRACT

This reference document for public school facility designers includes code items, principles that experience has shown to be desirable and practical, and best practices from a variety of professional sources. Organized into the four major engineering categories of electrical, mechanical, plumbing, and structural, these guidelines represent the thinking of a cross-section of design professionals and is consistent with the North Carolina Public Schools Facilities Guidelines. (GR)

electrical

hvac

Engineering Checklist for Public School Facilities

plumbing

structural

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ENGINEERING CHECKLIST
FOR
PUBLIC SCHOOL FACILITIES

FOREWORD

Educators, members of the community, and design professionals alike are aware of the impact of physical environment on teaching and learning. School facilities that foster the safest and most productive learning environments while affording long-term efficiency and value challenge the creativity and sensibility of all involved in the facilities-planning process. Engineering components that provide optimum short- and long-term infrastructure are basic to designs that create desirable school facilities.

This publication enumerates recommended minimum engineering guidelines for public school facilities design and is a supplement to the State Board of Education's *North Carolina Public Schools Facilities Guidelines.* We hope you find this information useful.

Phillip J. Kirk, Jr., Chair
State Board of Education

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INTRODUCTION

Designing school facilities that productively address current and emerging requirements for teaching and learning environments, safety, functional organization and management, and present and long-term value and economy of operation challenges the design professional as perhaps no other undertaking. Since, over time, quality of both structure and infrastructure will determine the ultimate success of a design, incorporation of the best available engineering components into the planning process is prudent.

The *Engineering Checklist for School Facilities* replaces the *Minimum Checklist for Mechanical and Electrical Plans and Specifications*. It updates, expands and re-formats information from the previous document to provide a comprehensive and useful tool for the designer of school facilities.

This publication identifies a variety of items of interest to engineers, architects, and educators engaged in the development of plans for public school facilities. Content covers major engineering elements, represents the thinking of a cross-section of design professionals, and is consistent with the *North Carolina Public Schools Facilities Guidelines*. Included are code items, principles that experience has shown to be desirable and practical, and best practices from a variety of professional sources. The *Checklist* serves as a resource for purposes of the mandated State Board plan review and comment process conducted by School Planning. Review comments must be considered by local boards of education in reviewing plans for proposed construction.

USING THE CHECKLIST

This publication is a reference document for designers of public school facilities. It is neither comprehensive nor all-inclusive, but provides a guide to pertinent engineering elements for use in plan development. Content in no way supersedes state or local codes or regulations; federal or state legislation regarding building design and construction, access, or safety; or other legal mandates.

The *Checklist* is organized into four major engineering categories--electrical, mechanical, plumbing, and structural. Additional notes and related information are placed appropriately, as needed.

Throughout the document, the term *shall* indicates items that are mandatory because of law, code, or regulation. *Should* indicates items that are standard practice or that experience has shown to be desirable. Questions regarding checklist items may be addressed to School Planning staff at the address shown on the front cover or by phone at (919) 715-1990.

ELECTRICAL

General

✔ Electrical plans shall include a single-line or riser diagram showing service conduit size, service wire size and type (or bus duct), panels, switches, over-current device sizes, transformers (when used in the secondary system), feeder conduit sizes, feeder wire sizes, and complete grounding and bonding details. Specifications shall describe quality of materials and methods of installation.

✔ Grounding and bonding details shall be shown by means of a separate diagram.

✔ North Carolina General Statutes require that all electrical equipment, devices, and apparatus sold and used in the state shall be evaluated for safety and listed by an accredited listing agency (G.S.66-35). Specifications shall indicate that requirement.

✔ Electrical plans shall include a numbered circuit diagram for each panel showing circuit use, circuit breaker size, circuit wire size, circuit conduit size, phase loads, and total panel load.

✔ An emergency system shall be kept separate from all other wiring (NEC 700).

✔ Where wire and equipment are oversized for future expansion, some notation on the plans can be helpful to all concerned.

✔ The entire system shall be color coded. Paint or tape should not be applied to No.6 or smaller wire.

✔ Two sets of colors should be used for color coding dual-voltage systems, such as 277/480 v or 120/208 v. Color standardization for the phase conductors should be red, black, and blue for 120/208 v systems; yellow, brown, and orange for 277/480 v systems.

✔ When long runs of wire are used, voltage drop (independent of spare capacity) should be considered. The maximum voltage drop should not exceed 5% of the nominal voltage.

✔ Electrical plans shall bear the seal of the engineer who is responsible for the design and who is required by law to inspect and issue a certificate of compliance upon project completion (G.S.133-1.1).

✔ All electrical plans and specifications for heating and air conditioning controls, general lighting, and plumbing wiring should be coordinated and shall comply with the NCSBC, Volume X.

✔ Wiring and final connections for heating, ventilation, and air conditioning controls should be a part of the mechanical contract, but all work shall conform to the NEC and, where required, be performed by a licensed electrical contractor.

✔ Electrical plans shall show the secondary voltage at the single line or riser diagram, in panel and other schedules, and in the lighting fixture listing. Acceptable secondary voltage systems include:
120/208 v, three-phase, four-wire, wye (for very small facilities)
277/480 v, three-phase, four-wire, wye (recommended for most new facilities)

✔ A single-phase system is acceptable only when the system in an existing facility is single-phase and the facility will remain very small after the addition or when it is not possible or economically feasible to extend three-phase service to the school site.

✔ Delta systems (120/240 v, three-phase, four-wire) are not recommended and should be used only for an addition to an existing facility that operates at that voltage and conversion to 120/208 v, wye is not economically feasible. Where no existing 240 v, three-phase equipment is in use, the system should be converted to 120/208 v.

✔ For step-down transformers within a secondary system, drawings should show details for transformer wiring, grounding, and bonding. See NEC 450 for over-current protection.

✔ Conductors supplied from the secondary terminals of dry-type transformers within secondary electrical systems must be provided with over-current protection, in accordance with the requirements of NEC 240. Conductors from single-phase transformers can be excepted. See NEC 384 for the sizing of conductors from the secondary of a transformer to the panel board.

✔ Step-down (dry-type) transformer locations are important safety and operational elements. They should never be located in wet areas or in areas that are to be hosed down, and should be mounted at least 18 inches above floor level to eliminate potential water hazards. Transformers should be located in properly ventilated areas such as equipment rooms, closets, or other similar areas not directly accessible to students. Refer to NEC 450.

✔ Specifications shall require all insulated conductors to be marked on their outer coverings to indicate voltage, type, and size for post-installation identification.

✔ Conductors should be copper wire, except that panel feeders over 100 amperes may be copper-clad aluminum with mechanical connectors. Split-bolt connectors are not acceptable.

✔ Because of the increase in capacity of the national power grid that connects most electric utilities in the country and the increase in the size and demand of new and renovated schools, short-circuit currents available at school service entrances are increasing to very high levels. The available short circuit current (or KVA) should be placed on riser or single-line diagrams to provide an awareness to electrical engineers and maintenance supervisors and ensure that proper coordination of electrical systems within the schools will be provided on all new construction.

✔ Computers, adjustable-frequency drives, ballasts, and numerous other electronic devices now installed in school construction projects cause non-linear loads and harmonics. Oversized neutrals and transformers designed for non-linear loads should be considered and used where necessary.

✔ Due to the sensitivity of electronic equipment now installed in new construction or renovations, transient and surge protection is usually required. These devices can be installed in service entrance panels or feeders and in panel boards or receptacles serving electronic equipment. Protection may be provided at one or any combination of these locations, based upon professional knowledge and judgment. Protection is required for telephone and data conductors--particularly those that enter the premises from outside sources and that run from building to building.

✔ The Americans with Disabilities Act affects numerous functions within the school that include (but are not limited to) sound, telephone, and fire alarm systems for the hearing impaired. Strobe lights or combination strobe/horn units are required for all classrooms, toilets, corridors and other places of assembly, and in specialized instructional areas. Sufficient emergency and exit lighting is a requirement of the ADA and the NCSBC.

✔ An electrical summary, either full or in part as is appropriate for a given school, shall be shown on the plans and shall include:

1. The new load
2. The existing load. If this information is not readily available, the owner should make arrangements to provide it through the services of the design consultant, use of demand readings from the electric utility, or some other means.
3. The capacity provided for known future expansion
4. The spare capacity provided, if not for future expansion. (Specify. E.g., for air conditioning.)
5. The total capacity of the service.

✔ A single 20-ampere circuit should be used for receptacles only in each general classroom. Additional 20-ampere circuits may be required for computer installation. Special classrooms can impose different considerations.

✔ In making buildings accessible to and usable by the handicapped, per the ADA and NCSBC, refer to Volume I-C of the NCSBC for locations of telephones, lighting switches, and other similar items.

✔ Electrical and mechanical engineers should work together closely to apply reasonable methods of energy management, ensure the control of all aspects of electrical energy usage, and to minimize operating costs. With regard to electrical and lighting system design, attention is called to Volume X of the NCSBC.

✔ In gymnasiums, gymtoriums, play, and other similar indoor spaces, mounting methods for overhead lighting fixtures are important. Fixtures should be mounted as high as possible while maintaining optimal function, be mounted on swivels, and incorporate safety chains. To prevent injury to students and others from falling fixtures or debris from damaged fixtures, protective lenses or wire cages should be used.

Service Entrance Feeder

✔ In addition to locating pad-mounted transformers (when used), the location of the nearest power pole should be shown on the plans.

✔ Service entrance feeders should be detailed and dimensioned, showing attachment points to structures and clearances of service wires over finish grades, drives, and roofs (NEC 230).

✔ Connections at service heads shall be made in accordance with the requirements of NEC 230.

✔ Underground services, both primary and secondary, are recommended in all cases except where the cost is unreasonable. Underground service routing should be shown on a site or plot plan.

Service Equipment

✔ All service equipment, including emergency systems, shall be bonded up to and including the first over-current device (NEC 250).

✔ Specifications shall cover bonding and bonding diagrams should be shown on plans.

✔ Where two or more conduits use the same jumper, bond wire used to carry the fault current of a parallel service shall be sized on the combined conductor capacity and not on the capacity of one set of conductors (NEC 250). An emergency system shall be bonded up to and including its over-current device (NEC 250-G).

✔ Surface-mounted switches, cabinets, metal raceways, boxes, and fittings mounted on surfaces subject to dampness shall not be attached directly to those surfaces. At least 1/4 inch of air space shall be provided between such enclosures and walls or other supporting surfaces. Cabinets or cutout boxes installed in wet locations shall be weatherproof (NEC 373).

✔ Cabinets and cut-out boxes in switch gear shall be increased in size to accommodate extra connections (NEC 373).

✔ Each building or structure shall have its own ground and its own disconnecting means as required by the NEC 230 and 250.

✔ Provide lightning protection at, or as near as possible to, the service entrance or main panelboard. Supplemental protection must be provided for electronic equipment and computers.

✔ Grounding electrode system connections shall be to the building water main (metallic pipe) and ground rods and shall be accessible. Points of attachment and sizes of grounding electrode conductors shall be indicated on the plans (NEC 205).

✔ Where ground wires are protected by the use of conduits, conduits and wires must be bonded at both ends of the conduits (NEC 250).

✔ Where a 480/277 v service is used and the main circuit breaker is 1000 amperes or higher, the main circuit breaker shall have a ground fault protection device.

✔ If non-metallic water supply pipe is proposed, the electrical engineer should communicate to the plumbing design engineer its inability to serve as an electrical ground and that metallic pipe is needed. Proper grounding must be established in accordance with NEC 250.

✔ Service equipment shall be referred to as service equipment and shall be UL labeled as such.

✔ For equipment-interrupting capacity, the fault current (or KVA) rating from the power company should be indicated on the plans at or near where the service entrance is indicated on the single-line or riser diagram (NEC 110-9).

✔ Electrical service equipment should not be located in boiler rooms due to the derating effect of heat on equipment and wiring. Where such equipment must be so located, it should be in a completely separate dedicated enclosure as far away from the heat source as possible. Under no circumstances should electrical equipment be located in a space with coal-fired or propane fired boilers. Where existing boiler rooms are below grade, renovations should relocate electrical equipment to other appropriate spaces.

✔ Strong emphasis should be placed on proper grounding. Many problems that result in equipment failure--particularly in electronic equipment--are caused by poor grounding, even when lightning protection is present.

Distribution Equipment

✔ Electrical equipment, such as panelboards, disconnect switches, starters, and toilet and corridor lighting switches, should be located to prevent student accessibility. Typical examples of such locations include office areas, storage closets, attics, mechanical equipment rooms, and "dry" custodial storage rooms. Keyed switching for toilet and corridor lighting is an acceptable alternative.

✔ Panel specifications must include special approved lugs where conductors are run in multiple or are used in through-feeders.

✔ Bolt-in breakers should be used in panels.

✔ Breakers should be numbered and branch circuits installed as shown on the plans; shop drawings of panels should match the plans.

✔ More than one solid or stranded wire shall not be allowed under a single lug or screw-type terminal unless approved for such use (NEC 110-14).

✔ Throated, insulated bushings should be used on all EMT connectors.

✔ Consider harmonic distortions from computers, copy machines, printers, lighting fixtures, and other equipment. Size feeder and panelboard neutrals accordingly and specify transformers for use with non-linear loads

✔ Spare conduits should be included where spare breakers are provided in flush-mounted panels.

✔ Proper panelboard protection is required (NEC 384).

✔ Provide lightning and surge protection where television, computer, telecommunications, or other electronic equipment is located.

✔ The use of transformers to convert 208 v to 240 v for use in instructional electric ranges is discouraged. 208 v equipment should be specified.

Branch Circuits

✔ Metal switch and receptacle cover plates are recommended.

✔ Moisture-proof switches and lighting fixtures shall be used in wash areas, shower rooms, freezer and refrigerator rooms, dishwasher locations, and other such places that are likely to be subjected to water or moisture (NEC 410; 370).

✔ Use GFI receptacles for whirlpools and within six feet of lavatories, sinks, and other wet locations.

✔ Do not use flush floor-type receptacles in kitchens or in other spaces subject to washing down or mopping.

✔ At least one duplex outlet is required in the boiler room and at least one shall be located within 25 feet of each piece of mechanical and plumbing equipment, to include that which is roof-mounted.

✔ Junction and pull boxes shall, as a minimum, be sized according to NEC 370.

✔ Provide disconnect switches for water heaters that are located out of sight of the panelboards feeding them.

✔ Each multi-wire branch circuit (NEC 210-4) shall be connected so the neutral will not carry more than the maximum load of any single "hot" conductor in the circuit. Oversized neutrals shall be used as required where "K"-type transformers supply equipment that produces harmonic distortion.

✔ All lock nuts must be tightened during installation (NEC 300).

✔ Branch circuits shall not be loaded to more than 80 percent of their rated capacity for continuous loads plus 100 percent of the non-continuous loads (NEC 210).

✔ Fluorescent fixtures mounted on combustible, low-density cellulose fiberboard shall be installed as required by the NEC (410-M).

✔ See *Volume X - Energy* of the NCSBC for lighting power allowances in watts per square foot.

Motors and Equipment

✔ Where raceway flexibility is desired at the point of connection to a motor or piece of equipment, flexible conduit must be installed as required by the NEC (350).

✔ Thermal overload protection shall be provided for each motor as required by the NEC (430-C). Running over-current protection for three-phase motors must be provided in each phase, as required by the NEC (430-B). Each motor shall be within sight of its disconnecting means. For this application, more than fifty feet shall be considered out of sight (NEC 430-H).

✔ Most new shop and kitchen equipment operates from 120 or 208 v, single-phase or 208 v, three-phase supply. Caution should be exercised in selecting 480 v equipment.

Emergency and Exit Lighting Systems and Power

✔ Emergency and exit lighting are required by the NCSBC (Volume I, Chapter 10: *Exit Illumination and Signs*). All school buildings, regardless of age, shall have both exit and emergency lighting fixtures.

✔ Illuminated exit signs shall be strategically placed where they can be seen from any position in corridors (both directions), gymnasiums, multipurpose rooms, cafeterias, auditoriums, media centers, and other assembly areas. Where corridors have smoke doors, exit fixtures usually should be located over the doors on both sides of the wall. LED (light-emitting diode) exit lighting fixtures should be used. Fluorescent lamps are available for use in exit lighting fixtures for normal power source illumination; incandescents (or halogens) for emergency lighting on battery output only.

✔ Battery-powered fluorescent lighting fixtures should not be used due to the high number of failures experienced. Halogen lamps should be used with battery-operated emergency lighting.

✔ Three-way and four-way switches shall not be used in emergency lighting systems (NEC 700).

✔ Manually-operated switches for exit and/or emergency lighting systems shall be accessible only to authorized personnel (NEC 700).

✔ Emergency lighting systems shall not be controlled from the stages of assembly areas (NEC 700).

✔ Cafeterias, auditoriums, multipurpose rooms, gymnasiums, and other assembly areas shall have emergency illumination, as shall all interior spaces that exist without available natural light and that are occupied by students. Un-switched night lights shall be provided in these same spaces.

✔ Where metal halide or high pressure sodium lighting is used, supplemental lighting should be used to provide illumination during momentary power outages. Metal halide fixtures, in particular, take an extended period of time to return to full illumination. Fluorescent lighting is recommended for the supplemental system, but some metal halide and high pressure sodium fixtures can accommodate quartz-type supplemental fixtures.

✔ The NCSBC (Volume I, Table 1016) requires the application of specific types of emergency power sources. Battery-powered exit and emergency illumination systems are recommended due, in part, to ease of maintenance. On larger facilities, emergency generators may be more cost effective or the owner may have a preference for them.

Fire Alarm; Smoke and Heat Detection Systems

✔ Manual fire alarm systems are required for all new school buildings and for additions and major renovations, regardless of whether existing facilities have fire alarm systems. Automatic fire alarm systems are acceptable alternatives (NCSBC, Chapter IX).

✔ Automatic smoke detectors are required for specific locations, such as both sides of smoke doors (NCSBC, Volume III, Chapter 4: *Fan Shut-down and Control*).

✔ Rate-of-rise heat detectors should be installed in boiler and furnace rooms and in rooms in which paper products and/or other flammable materials are stored.

✔ Alarm horns/strobe lights shall be located to satisfy ADA and fire safety code requirements. Outside alarms are recommended to alert persons not to enter and to alert neighbors when facilities are unoccupied.

✔ All smoke and heat detectors, including those which activate the shut-down feature of air handling units, shall be tied in to the fire alarm system and shall activate all alarms.

General Illumination

✔ Good lighting system design necessary to create a proper visual environment can result from close cooperation between design professionals and educators. Four major factors that must be considered in developing the design are levels of illumination; reflectances and ranges of reflectances; brightness and brightness ratios; and contracts

✔ Recommended levels of illumination are provided later in this section. See also ANSI/IES RP3 (latest edition) *Guide for Educational Facilities Lighting*.

✔ The following is a typical procedure for the design of a lighting system.

- Establish desired environment:
    - Brightness and brightness ratios
    - Colors and textures
    - Methods of daylighting and daylight controls
- Establish reference task and required illumination levels
    - Classrooms
    - Special-purpose areas (labs; libraries; shops; etc.)

Establish general illumination system

- Distribution characteristics and energy usage of light sources
- Coordinate with effect of task visibility
- Coordinate with total environment
  - Characteristics of heat and noise production
  - Color acceptability
  - Special and aesthetic characteristics

Establish supplemental illumination (task lighting)

- Chalk and marker boards
- Special tasks
- Special areas

Establish audiovisual requirements

Analyze economics (life-cycle cost analysis)

- Capital expenses
- Maintenance expenses
- Electrical energy costs

✔ Double switching is required in rooms larger than 200 square feet (NCSBC, Volume X: *Lighting*). Where three- or four-lamp fixtures are used, inside lamps should be uniformly switched separately from outside lamps.

✔ It is preferable to use electronic ballasts and T-8 lamps (or use energy-saving lamps and ballasts) when replacing existing fixtures. Electronic ballasts will eventually replace most uses for magnetic ballasts. Replace lamps or ballasts with identical types.

✔ Outdoor lighting for security, walkways, and parking lots should provide adequate illumination for moving to and from buildings and to discourage vandalism. High pressure sodium fixtures are strongly recommended. Metal halide fixtures are an acceptable alternative.

✔ Wiring and lighting athletics fields involve consideration of lighting intensities; fixture selection, arrangement, and quality; and safety of the installations (NEC and NESC). Underground distribution of 277/480 v is recommended with metal halide fixtures. High voltage distribution by school systems is not recommended due to a general lack of adequate equipment and expertise.

✔ Incandescent lamps use five times the energy and power required for fluorescent or metal halide lamps and should only be used in pipe chases and storage rooms and for floodlighting of stages. Mercury vapor lamps use twice the energy and power of metal halides and should not be used. Dimming equipment can be used on fluorescent and metal halide fixtures. Self-extinguishing metal halide lamps (and mercury vapor, if used) shall be used to prevent ultraviolet radiation burns when broken.

✔ Motion detectors, infrared, or other electronic switching devices sensitive to the presence of people are recommended. Where people enter and leave a room frequently, a 10-minute delay feature to prevent damage to fluorescent or metal halide lamps and ballasts is recommended.

✔ Interior lighting systems can be controlled by photoelectric switches to reduce inside lighting levels when natural lighting permits but to allow full artificial illumination when conditions warrant. Careful consideration must be given the design of switching circuits, since damage to fluorescent, metal halide, and high pressure sodium lamps and ballasts can result from the frequent switching caused by a partly cloudy day.

✔ North Carolina General Statutes provide for public schools to contract for energy conservation measures for existing facilities only. School systems may contract for new lighting, heating, insulation, air conditioning and other energy conservation measures and use the resultant savings over a maximum period of eight years to pay the contractors. For a new lighting installation, it is recommended that contractors be required to meet the IES-recommended illumination levels indicated later in this section. As an example, a system designed to provide only 30 foot-candles of illumination in a classroom, while resulting in lower energy costs, is not acceptable, based upon the recommended range of 50 - 75 fc. Lighting systems should not be replaced at their existing illumination levels if those levels are below IES recommendations.

RECOMMENDED LIGHTING SYSTEMS WITH ILLUMINATION LEVELS

INTERIOR LOCATIONS	MAINTAINED ILLUMINATION IN FOOT CANDLES* MINIMUM	MAXIMUM	TYPE OF LIGHTING FIXTURES
AUDITORIUMS			
SEATING AREA	10	15	FLUORESCENT (DIMMING OR MULTIPLE SWITCHING)
STAGE SET-UP	20	30	FLUORESCENT
CONCERTS ON STAGE	50	75	FLUORESCENT
DRAMA WITH ACCENTS	VARIABLE	VARIABLE	INCANDESCENT (TRACKS WITH DIMMING EQUIPMENT)
CAFETERIAS			
KITCHEN/SERVING AREA	50	75	FLUORESCENT
DINING ROOM	10	20	FLUORESCENT
CASHIERS	20	30	FLUORESCENT (TASK LIGHTING MAY BE HIGHER)
DISH WASHING	20	30	FLUORESCENT (LISTED FOR WET LOCATIONS)
CLASSROOMS			
GENERAL	50	75	FLUORESCENT
ART	50	75	FLUORESCENT
COMPUTER	50	75	FLUORESCENT (INDIRECT LIGHTING)
DRAFTING	75	100	FLUORESCENT(TASK LIGHTING PREFERRED)
STUDY HALLS	50	75	FLUORESCENT
HOME ECONOMICS	50	75	FLUORESCENT
LABORATORIES			
GENERAL	50	75	FLUORESCENT
DEMONSTRATION	100	150	FLUORESCENT (TASK LIGHTING)
LIPREADING	100	150	FLUORESCENT
MUSIC	50	75	FLUORESCENT
SEWING	75	100	FLUORESCENT (TASK LIGHTING)
SHOPS	50	75	FLUORESCENT (HIGHER LEVELS CAN BE USED FOR DETAIL WORKS)
TYPING	50	75	FLUORESCENT
CORRIDORS AND STAIRWELLS (USE REMOTE OR KEYED SWITCHING)			
MIDDLE AND HIGH	20	30	FLUORESCENT
ELEMENTARY	10	15	FLUORESCENT
TROPHY CASES	50	75	COMPACT FLUORESCENT
WALL "WASHING"	MIN. AMOUNTS		COMPACT FLUORESCENT
EXIT LIGHTING FIXTURES	N/A	N/A	LIGHT EMITTING DIODES (LED'S)
GYMNASIUMS - MULTIPLE SWITCHING TO OBTAIN VARIOUS LEVELS - COMPETITION GAMES VERSUS PHYSICAL EDUCATION)			
COMPETITION BETWEEN SCHOOLS	30	50	METAL HALIDE
PHYSICAL EDUCATION-MULTIPURPOSE AREAS	20	30	METAL HALIDE (OR FLUORESCENT IN EXERCISE AREAS)
LOCKERS AND SHOWERS	20	30	FLUORESCENT (LISTED FOR WET LOCATIONS)
ELEMENTARY (MULTIPURPOSE)	20	30	METAL HALIDE OR FLUORESCENT
MECHANICAL, ELECTRICAL & BOILER ROOMS	30	50	FLUORESCENT (INDUSTRIAL FIXTURES) OR INCANDESCENT IF ON WHILE ONLY "TEMPORARILY" OCCUPIED

INTERIOR LOCATIONS	MAINTAINED ILLUMINATION IN FOOT CANDLES* MINIMUM	MAXIMUM	TYPE OF LIGHTING FIXTURES
MEDIA CENTERS			
READING ROOM, CHECK IN/OUT, CARD FILES	50	75	FLUORESCENT
BOOK STACKS, MAGAZINE RACKS	30	50	FLUORESCENT
OFFICE AREAS	50	75	FLUORESCENT
AV AND OTHER STORAGE	7 ½	10	FLUORESCENT
AV REPAIR	75	100	FLUORESCENT (TASK LIGHTING)
OFFICES			
GENERAL OFFICE WORK	75	100	FLUORESCENT
CLOSE WORK	100	150	FLUORESCENT (TASK LIGHTING)
TEACHER WORK ROOM	30	50	FLUORESCENT
CONFERENCE ROOM	30	50	FLUORESCENT
STORAGE ROOMS, PIPE CHASES, ATTICS, CRAWL SPACES	7 ½	10	INDUSTRIAL FLUORESCENT (OR INCANDESCENT IF ON "TEMPORARILY" WHILE OCCUPIED)
SWIMMING POOLS	7 ½	10	METAL HALIDE OR FLUORESCENT (WET LOCATION APPROVED)
WASHROOMS/GANG TOILETS	20	30	FLUORESCENT (USE REMOTE OR KEYED SWITCHING)
WASHROOMS/FACULTY TOILETS	10	15	FLUORESCENT

EXTERIOR LOCATIONS (ALL FIXTURES SHALL BE LISTED FOR WET LOCATIONS AND OUTDOOR USE)

BUILDING EXTERIOR (FOR SECURITY PURPOSES)	1	1 ½	HIGH PRESSURE SODIUM OR METAL HALIDE
PARKING LOTS AND WALKWAYS	1	1 ½	HIGH PRESSURE SODIUM OR METAL HALIDE (COMPACT FLUORESCENT CAN BE USED FOR WALKWAYS)
SPORTS COMPLEXES**			
SOCCER/FOOTBALL STADIUM	30	50	METAL HALIDE
BADMINTON/VOLLEY BALL/TENNIS COURTS	20	30	METAL HALIDE
BASEBALL/SOFTBALL			
OUTFIELD	15	30	METAL HALIDE
INFIELD	20	50	METAL HALIDE
SEPARATE RUNNING TRACKS (NOT A PART OF A FOOTBALL OR BASEBALL STADIUM)	15	15	METAL HALIDE
**REFER TO NCHSAA FOR THEIR REQUIREMENTS			

*BASED ON ILLUMINATING ENGINEERING SOCIETY OF NORTH AMERICA (IES) RECOMMENDATIONS

Sound, Clock, and Class-Change Systems

✔ Sound systems should provide school-wide sound distribution from a single location and should also be designed for two-way communication. In the initial design, it is recommended that the degree of system sophistication be limited by its intended uses.

✔ Clock and bell systems are recommended for the orderly control of class periods within the school day. Systems and equipment should be kept as simple as is practical to minimize operational and maintenance costs.

✔ Complex clock systems can be expensive to purchase and maintain. Clocks that operate directly from 120 v receptacles or batteries are recommended, unless an integrated technology system provides time display on computer and television monitors and/or other electronic display panels.

✔ For all installations of Television Reception and Distribution Systems (TVRD), Master Antenna Television (MATV), Closed Circuit Television (CCTV), Community Antenna Television (CATV), Multiple Source Television (MSTV), and computer, telephone, and data systems, a recommended guide for cable and equipment installations--*STO-1000*--is available through the General Services Division, State of North Carolina, in Raleigh.

HEATING, VENTILATING AND AIR CONDITIONING

General

✔ North Carolina Department of Labor boiler and tank operating certificates are required for all boilers and certain water heaters.

✔Fire walls and each required duct fire damper shall be shown on the plans.

✔ Provide UL fire stop penetration details on the plans for each type of penetration.

✔ Motor overload protection shall be specified to be in accordance with the NEC. For three-phase motors, protection shall be provided for each of the three phases.

✔ A complete heating and cooling summary shall be shown, either fully or in part (as is appropriate for a given school), on the plans and shall indicate:

1. The existing load. Where this information is not readily available, the owner should make arrangements to provide it to the designer.
2. The new heating and cooling loads
3. Capacity provided for known future expansion
4. Spare capacity provided, where different from (3.) above
5. Domestic hot water load, where applicable
6. Net SBI or IBR capacity of the boiler(s), where applicable

✔Air-handling units shall not be located in rooms that contain boilers.

✔ Electric resistance heat should not be used for comfort space heating unless it is shown, through a life-cycle cost analysis, to be the most economical type over the life of a facility.

✔ Heating and cooling design conditions shall be stated on the plans.

✔ Mechanical plans shall bear the seal of the engineer who is responsible for the design and who shall inspect and issue a certificate of compliance upon completion of the project (G.S. 133-1.1).

✔ The engineer should select HVAC equipment with a low noise level that does not hinder instructional activity. Noise levels in classrooms should not exceed the level of NC 30.

✔ Record drawings should be provided to the owner at the completion of the project. This service is not usually covered in the AIA standard contract and will need to be added to the contract.

✔ Proper clearances for service and maintenance procedures shall be provided when positioning HVAC equipment. This is a requirement for electrically operated equipment (NEC 110-16; 17). It is not desirable to have equipment located where service procedures require ladder access or where ceiling grids or building structure must be removed for equipment replacement.

✔ When located outside, HVAC equipment should be enclosed to prevent unauthorized access and malicious damage. Chain link fences and brick walls with gates are examples of typical enclosures.

Selection of a System

In the design of an HVAC system for a school, the following are some factors and objectives that need to be considered as a part of the selection process:

✔ Room temperature and humidity control
✔ Times and loading of occupants in spaces
✔ Ventilation rates and indoor air quality
✔ Control of noise in the classroom environment
✔ System first cost
✔ Energy use and efficiency
✔ Ease of operation and maintenance
✔ Reliability of the system and long life of the components
✔ Flexibility and adaptability of the system
✔ Space requirements and/or availability of space
✔ Types of fuels available
✔ Energy management control systems

The most common indoor environmental complaint is poor ***temperature control***. The ideal solution is to have individual room temperature control for each classroom. The next step down in temperature control would be to have groups of two or more classrooms each having the same directional exposure be controlled from a single thermostat. Temperature control will be lost, to some degree, when some classrooms are vacated for a period of time while others are not.

The design should provide for control of ***relative humidity*** at or below 60 percent in all spaces. More precise control will be required in certain areas, such as the media center.

Areas such as auditoriums, cafeterias, and gymnasiums have high ***concentrations of students*** for short periods of time and should be controlled separately from other spaces. Other spaces, such as offices, may have a very different ***time of occupancy*** than the classrooms and other areas of the building and may need to be on a system separate from the central system.

Noise emanating from HVAC equipment within the classroom can be disruptive to the teaching/learning process. Typically, the worst acoustical arrangement is packaged equipment, mounted inside the classroom, that contains the compressor. Unit ventilators or fan coil units, with only a fan, mounted on the floor or at the ceiling can also be quite noisy. Often a child's desk is placed close to one of these units and that child is at a disadvantage. The best arrangement, acoustically, is to remove the mechanical equipment from the classroom as far as practical using sound attenuating ductwork to transmit the heating and cooling to the classroom.

The ***energy efficiency*** of a system or component should be given strong consideration. When available, lower-cost fuels should be used. Reheat systems should be avoided except in the case of a dehumidification cycle required in an area such as the media center.

Systems that are ***difficult to maintain*** invite situations where the equipment is not properly maintained and the result is sometimes equipment failure and indoor air quality problems. Required maintenance for a particular type of system should be matched to maintenance personnel capabilities as much as possible. However, systems that require maintenance within the classroom or above ceilings (from ladders) should be avoided where possible. Rooftop equipment is often not well maintained, especially when good access is not provided. The most desirable arrangement is to have the mechanical equipment floor mounted in mechanical rooms or on mezzanine equipment spaces that have stair access from a space large enough to hoist equipment up or down to the main level.

System ***reliability*** is generally determined by good design, proper installation, equipment maintenance and component life. Typically, heavier-duty central equipment will have a longer life and provide more reliability.

The system design may need to provide the flexibility to accommodate changes in classroom function or future school expansion. It might be feasible to provide spare capacity in some components, such as boilers or chillers.

Fuel Types

Fuel oil or natural gas should be used for heating, where available, because of their relatively low cost. Fuel oil is somewhat lower in cost, but when considering the expense of a fuel oil tank and additional maintenance costs, natural gas is generally the better choice when it is available. Electric resistance heat and propane gas are very high in cost and should be avoided except in some specific applications where it can be shown to be practical.

System Types

Recommended System

The following components of a central system are recommended because they provide long-term reliability, excellent room temperature control, low operating cost, moderate first cost, low room noise level and ease of maintenance.

A. Central air-cooled chiller(s)

B. Natural gas or oil-fired central boiler(s)

C. 4-pipe chilled water/hot water piping system

D. Air handling units (AHUs) located in dispersed mechanical rooms or mezzanine areas providing a separate zone for each individual classroom

The following are alternatives to the above recommended system:

ALTERNATIVE COMPONENT/SYSTEM	ADVANTAGES	DISADVANTAGES
2-Pipe Circulation System in lieu of 4-Pipe.	Lower initial cost.	Must shut down system for a day or two to switch between heating and cooling mode. System not applicable to some building designs that require simultaneous heating/cooling.
Same system except each AHU serves 2-5 classrooms.	Slightly lower first cost.	Having more than one classroom on a single thermostat is a compromise in comfort.
Fan Coil Units or unit ventilators mounted at ceiling in each classroom in lieu of AHUs.	Individual room control. Moderately lower cost than AHUs (No ductwork required). Don't occupy floor space.	Noisy. Difficult to service (ladder). Poor air distribution. Routing of condensate drain line can be difficult. Moderate life of unit. Not easy to include fresh air.

Unit Ventilators in lieu of AHUs.	Individual room control. Slightly lower cost than AHUs (no ductwork required).	Somewhat noisy. Fresh air is difficult for interior spaces. Take up space under windows. Care must be taken to avoid coil freeze-up. Unsightly if piping is not concealed. Better filtration not possible.
Multi-zone AHUs.	Centralized maintenance. Can isolate noise in a central location.	High first cost with extensive duct system.
Fan Coil Units mounted above ceiling in corridors with short ducts running to classroom diffuser(s) in lieu of AHUs	Individual room control. Slightly lower cost than AHUs. Don't occupy floor space.	Difficult to service. (ladder) Routing of condensate drain line can be difficult. Moderate life of unit.
Water-cooled Chiller (in lieu of air-cooled).	Good performance and reliability. Energy efficient.	High cost. Maintenance/treatment of cooling tower not practical for most school systems.
VAV System with separate zone for each classroom.	Excellent individual room control.	Very costly system. Very difficult to maintain requirements for fresh air. High maintenance cost. Can be noisy if units are above classroom ceilings. Requires re-heat.
Hydronic Heat Pumps.	Relatively low first cost. Only one uninsulated pipe loop required. Energy savings during simultaneous heating/cooling.	Multiple compressors to maintain. Cooling tower maintenance. Noisy if mounted in or above classrooms.

Geothermal (ground-coupled) Hydronic Heat Pumps.	Individual room control. Good reliability. Very low operating cost. No above-ground outdoor equipment required.	Drilling of wells and ground-loop piping is very costly. Requires a lot of land for wells and even more for horizontal loops.

* Notes:
As you approach smaller zone/individual room control, both initial and maintenance costs increase.

As you approach large zone/whole building with one control, reliability increases and initial and maintenance costs decrease; however, potential problems from temperature variation in rooms increases.

Boilers

✔ Boiler room floors should be located at or above grade elevation.

✔ Boilers and pressure vessels shall be installed with adequate clearance for proper operation and inspection and in accordance with the NCBPVR, Section .0400, Rule .0413.

✔ For tube cleaning and removal, steel boilers shall have minimum front clearance equal to the length of the longest tube plus 12 inches.

✔ When sections are added to a cast iron boiler, the nomenclature plate and safety valve shall be changed to comply with the new rating.

✔ Boiler ratings

1. The SBI net ratings should be shown for steel boilers. Boiler selection should be made with respect to load, piping, and pick-up.
2. The IBR net rating for cast iron boilers should be specified.
3. Where catalogs show only gross boiler ratings, care should be taken to determine true net ratings. Selection should be made with respect to both direct connected load and necessary piping and pick-up losses (as applicable to schools).

✔ Safety and relief valve capacities shall be specified on the plans.

✔ Safety and relief valve discharges should be installed in accordance with the NCBPVR.

✔ Discharge lines from safety and relief valves shall be supported other than by the valves themselves.

✔ Manholes, rod holes, nomenclature plates, or ASME stamping on boilers shall not be covered or obstructed by piping or other components.

✔ Boiler bottom blow-down valves and piping shall be sized and arranged in accordance with the NCBPVR, Section .0400, Rule .0411.

✔ Boiler piping should not restrict the use of smoke hood clean-out doors, manhole openings, and plugged openings.

✔ A four-inch thick (minimum) concrete base should be installed under a boiler.

✔ For cleaning purposes, cross-type fittings should be used on steam boiler piping at water columns and feeders and at low water cut-offs.

✔ Each steam or hot water boiler application should be engineered specifically to suit the system it will serve. Heating boiler design should incorporate a degree of spare capacity without full stand-by equipment--preferably, two boilers sized at 60-65% each. Too little capacity can result in serious problems, such as difficulty with holding the water line. When specifying steam boilers, care should be taken to properly evaluate steam and water capacities (volumes) of boilers, in relation to the systems served and the heating fuel to be used. The method of feed water control should be shown in detail on the plans.

✔ Heating fuel should be light oil or natural gas. Where natural gas is available, dual fuel burners for both gas and oil should be used.

✔ Oil burner controls

1. Cadmium cell relays are satisfactory for firing rates of approximately three gallons per hour or less.

2. Electronic program-type controls should be used for firing rates greater than three gallons per hour. In addition to providing safety cut-out, these will pre-purge and post-purge the boiler.

✔ Feed or make-up water to boilers should be introduced at the return connection to the boiler or to the air line for an expansion tank, and shall be piped to comply with installation requirements of the NCBPVR.

✔ Low water cut-offs and safety water feeders for steam boilers should be set two and one-half inches below the normal water level of the boiler (NCBPVR, Section 5, Rule 20).

✔ Condensate pumps should be sized for two to three times the net capacities of steam boilers.

✔ Steam condensate pumps should have cast iron receivers.

✔Gas burners for boiler firing may be of the atmospheric (non-pressure) type in the lower range of sizes (up to approximately 500,000 btu input). Above that size, power burners should be used. Factory-engineered units incorporating boiler and burner are recommended.

✔ Proper application and use of the best available grades of gas combustion equipment and safety controls are mandatory. Equipment and controls should be specified in strict accordance with manufacturers' recommendations and best accepted practices, and shall meet requirements of the AGA and IRI. Combustion control equipment set forth by manufacturers is often minimal; hence, components should be carefully engineered to provide the degree of performance and safety needed in school applications. (See the NCBPVR, Section .0400.)

✔ The net free area of boiler room combustion air louvers shall meet the requirements of the NCBPVR, Section .0400, Rule .0419. Some local inspectors might require compliance with NCSBC.

Stack and Breeching

✔ Stack

1. A hinged cleanout door should be specified for the chimney.
2. A flue lining is required (NCSBC, Volume III, Chapter 9) and should be coordinated with the architect.
3. A pre-cast flue thimble or firebrick lining is necessary where the breeching enters the chimney, and should be coordinated with the architect.
4. Thimble, breeching and chimney connections must be airtight for efficient operation.
5. Where metal chimneys are specified, as for oil- or gas-fired equipment, provisions of the NFC, Volume 4, NFPA 211 shall apply.

✔ Breeching

1. Breeching should be supported independent of the boiler.
2. Adequate cleanouts should be provided to promote easy periodic cleaning.
3. In forced-draft applications, barometric dampers are not usually required.
4. In forced-draft boiler installations, a locking-type damper should be installed in each separate breeching.

Oil Storage Tanks

✔ Oil storage tank capacity should reflect the size of the heating plant and local service and delivery options. A minimum capacity of 10,000 gallons is normally necessary to attain fuel cost savings through central purchasing. Check with owner before finalizing tank size.

✔ Where underground tanks are necessary, they should be fabricated of heavy steel or fiberglass, should be double walled, and should bear the Underwriter's label. Steel tanks should be fiberglass coated.

✔ Underground tanks should be adequately anchored by means of concrete pads and/or suitable anchor hardware.

✔ Tanks shall be installed in strict accordance with governing building (fire) codes and environmental regulations.

✔ Above-ground tanks, with properly designed and constructed containment, are preferred.

✔ The filler end of tanks should be four to six inches lower than the other end.

Steam, Hot Water, and Chilled Water Piping

✔ Heating or cooling pipes should be placed underground or below slab on grade only if there is no other option. Steam condensate lines, which must necessarily be placed underground in certain applications, should be of Schedule 80 steel or some other material that is especially corrosion resistant.

✔ Pipe insulation in boiler rooms and mechanical rooms should have protective canvas or aluminum jacketing applied over the insulation system. Jackets provided as a part of the insulation system are not sufficient.

✔ Where it is necessary to install steam condensate piping underground, piping should be located outside the periphery of the building wherever possible, rather than beneath the slab. Pipe tunnels might be feasible in some applications.

✔ Exposed outdoor water piping should be protected from freezing with electric heat tape or a glycol solution. Insulation should be covered with a protective metal covering.

✔ Provision for expansion of piping should be provided by use of expansion fittings, swing joints, or expansion loops.

✔ Provision should be made for the removal of traps, valves, strainers, etc. through the use of unions, except where fittings are of the combination union or flange types.

✔ Piping hook-up details should be shown on plans for each piece of heating and cooling apparatus, to include boilers, pumps, hot water generators and tanks, converters, radiation units, forced air heating and cooling units and drip assemblies, and any points where special piping conditions exist.

✔ Flow direction arrows for all heating and cooling (water) lines should be shown on plans.

✔ Locations of piping runs, such as above ceiling, exposed at the ceiling, or below floor, should be indicated by notes on drawings.

✔ Four-pipe systems are preferred, but where two-pipe systems are used the following shall be observed. In dual temperature hot water-chilled water systems that incorporate a boiler and a chiller, piping shall be arranged and valved so that cold water cannot circulate through a boiler and hot water cannot circulate through a chiller. This can be accomplished by using a line-sized combination check and balancing valve on the boiler or chiller lines located adjacent to the tie-in at the dual temp lines. A three-way modulating valve with appropriate thermostatic controls shall be used to automatically change the system over from heating to cooling or cooling to heating without creating thermal shock to the boiler or chiller.

✔ Provide valved fill bypasses around pressure regulating valves in make-up water assemblies serving hot water or chilled water piping systems. Provide a pressure gauge and cock.

✔ Isolation shut-off valves should be provided at each location where piping enters or leaves a mechanical room or a building. Provide valving that is easily accessed for isolation of each wing of a building.

✔ Provide air control systems for hot water, chilled water or dual-temperature systems. The air control system is to consist of ASME compression tanks, tank fittings, drains, properly sized pressure reducing valves and air separators with tangential connections. Show on the plans the pressure required at the pressure reducing valve to provide 4 psig pressure at the high point of the system with the pump off.

✔ Reverse return design is recommended for hot water and chilled water piping systems, where practical. Automatic flow control valves may be used as an alternative, installed on the leaving side of the coil after the control valve. A strainer with hose bibb blow-down valve shall be installed on the entering side of each coil. Automatic flow control valves and strainers should be the same size as the piping, except at the connection to the modulating control valve where they can be reduced no more than one pipe size. The engineer should specify the minimum CV of the valve.

✔ In multiple-boiler installations, the piping arrangement should be such that water flow is equally divided through each boiler. Pumping shall be away from boilers and to the system.

✔ Compression tanks shall be specified to meet ASME Code construction and should be so stamped. Bladder-type tanks may be used in lieu of compression tanks. Sight glasses should not be installed on tanks unless they are equipped with isolation ball valves.

✔ All manual balance valves and automatic flow control valves should be installed on the leaving side of the coil, after the control valve, to reduce coil noise and air problems.

✔ Manual air vents, rather than automatic, should be used.

✔ Pumps shall have a cut-off valve on each side for servicing. One of these valves may be a combination shut-off, center guided non-slam check, and balancing valve. The engineer should specify the minimum CV of the valve.

✔ Provide a system piping flow diagram on the drawings for both chilled water and hot water systems.

✔ All modulating control valves, combination valves, check valves, balancing valves, strainers and on/off valves should have their minimum CV or maximum allowable pressure drop specified, to control the hydronic system efficiency.

✔ All pump schedules should include maximum allowable suction and discharge velocities or minimum connection sizes, along with the NPSHR for all cooling tower pumps.

✔ Parallel pumping systems should be considered for reasons of economy. When parallel pumps are selected the standby capacity in GPM at the point of staging should be specified.

✔ Plans or specifications should call for all piping in boiler rooms, mechanical rooms and other accessible locations to be labeled.

Gas Piping

✔ For gas piping installation and testing, see Gas Systems under PLUMBING.

Heating Systems

✔ The NCSBC does not permit any type of direct-fired gas heating system inside the building.

✔ Individual control valves should be sized large enough not to restrict capacities. Two-position valves should be full pipe size.

✔ Control valve actuators need to be sized to fully close against the full shut-off head of the pump.

✔ Modulating control valves should be sized with a wide open pressure drop large enough to offer good control through the full range of operation. Usually a valve pressure drop of approximately 25% of the system pressure drop is adequate.

✔ To prevent cold operation, strap-on limit controls should be installed on unit and cabinet heaters not also used for ventilating and cooling. For example, unit heaters in shops that circulate air separate from heating may include an additional on-off automatic hot water control valve to accomplish this.

✔ Valves, balancing cocks, and traps should be accessible--not behind covers without access panels.

✔ Fronts and ends of radiation covers should be a minimum of 16 gauge steel.

✔ For reasons of economy, installation of full standby pumping is not recommended. When warranted, a spare motor can be provided. In some systems, parallel pumping may be a feasible and worthwhile alternative.

Cooling Systems

✔ Cooling should be specified for the entire school facility, with the exception of mechanical/electrical equipment rooms, janitor rooms and certain storage rooms.

✔ Consideration should be given to providing specific humidification control in areas such as media and technology centers, computer rooms, science prep rooms, and uniform and musical instrument storage areas.

✔Two-position (on-off) control of chilled water coil control valves is preferable over modulating control because of better space humidity control. If modulating valves are used, the system should include a dehumidification sequence of operation.

✔ When multiple chillers are used, terminal cooling coils should be controlled with two-way valves and variable-speed pumping should be used. This allows the first chiller to fully load up at part load and results in a more efficient system.

✔ In central-plant air conditioning systems, types of refrigeration equipment--reciprocating, rotary, centrifugal, air-cooled or water-cooled--should be evaluated and selected carefully, based upon capacity, flexibility, space requirements, noise and vibration factors, operation and maintenance requirements, and load diversity.

✔ Self-contained, unitary air conditioning equipment is acceptable, but should be carefully evaluated with respect to life expectancy, efficiency, service, and noise factors.

✔ Window-type air conditioning units are not recommended and should only be selected as a last resort. They should not be used in classrooms.

✔ Larger group toilets should be cooled and heated.

✔ Heat reclaim equipment may be used for fresh air intake if it is found to have a reasonable payback in operating cost savings.

✔ Five-year warranties should be specified for air conditioning compressors.

✔ Noisy outdoor equipment should not be placed adjacent to classroom windows or in other areas where a distraction might result.

AHU, Fan Coil and Unit Ventilators

✔ Flexible connections should be provided at all ductwork connections to units.

✔ Condensate drain pans should be positively sloped with the outlet in the bottom of the pan so that water never collects in the pan and supports microbial growth.

✔ Provide air-handling units with metal filter access racks and hinged filter access doors with cam locks.

✔ Filters with an ASHRAE dust-spot minimum efficiency of 60% should be specified and maintained in units. Better filtration will remove a large part of the fungi and bacteria that tend to collect on the wet cooling coil. It also deprives the microorganisms of nutrients (dust, lint, etc.) that are necessary for growth. Cleaner, more efficient coils will tend to offset the slightly higher cost of more efficient filters.

✔ Low-leakage dampers should be specified for fresh air intakes. Damper controls should have the dampers positively closed when the units are off.

✔ Units should be supported on vibration isolation equipment. Special attention should be given units mounted on the floor of the second level.

✔ Do not locate air handling units in the same room as boilers.

✔ Auxiliary drain pans should be mounted below units that are installed above ceilings or on the second level without floor drains. The drain pan shall include a float switch that will stop the unit if water collects in the auxiliary pan.

✔ Adequate service space is essential for air-handling and fan coil units.

Air Distribution

✔ Seal all ductwork joints airtight.

✔ Ceiling diffusers in classrooms should always be the adjustable-throw type.

✔ For classrooms 1,000 square feet or less, a total of four (4) four-way ceiling diffusers is recommended.

✔ Provide at least three (3) diameters of straight flex duct at the diffuser inlet.

✔ Provide a balancing damper at each branch duct takeoff from a main duct so that air balancing can be done at that point rather than with the diffuser damper.

Ventilation and Indoor Air Quality

✔ Mechanical ventilation may be provided by means of either separate fresh-air intake systems (with or without accompanying exhaust) or integration with the heating-cooling system. The latter is recommended.

✔ The classroom ventilation rate should be 7.5 cfm of fresh air per person. Louvers and fresh air ducts should be sized to handle 15 cfm per person for future special ventilation needs.

✔ Avoid pulling fresh air off flat roofs because of roofing odors, high temperatures and standing water.

✔ Where ventilation air is introduced, adequate provisions may need to be made for air relief.

✔ Mechanical ventilation is essential to gymnasiums and locker rooms, certain storage rooms, dressing rooms, laundries, toilets, and janitor closets.

✔ Year-round timed operation of ventilation equipment in uniform storage areas is recommended.

✔ Sound traps should be installed in duct systems serving two or more toilets or the ducts should be offset so there is no direct path between the toilets for sound to follow.

✔ Ventilation to food storage areas should be provided by introducing fresh outside air near the floor and expelling exhaust air through the roof by gravity flow.

✔ Paint spray rooms are considered hazardous and require special ventilation and safety treatment. Commercial booths are recommended. Where other equipment is installed, related regulations and codes should be carefully investigated.

✔ Adequate quantities of make-up air should be provided in spaces equipped with exhaust fans. Filtering and tempering of make-up air is appropriate for some applications.

✔ Gutters are prohibited on kitchen exhaust hoods. Hoods should be mounted a minimum of six feet, six inches and a maximum of seven feet from the floor. A minimum of 12 inches vertical rise should be provided on the inside of the hood before taper begins. Hoods should cover the entire area of cooking equipment and extend at least six inches beyond the equipment. Automatic fire extinguishing equipment shall be installed in the kitchen hood (NCSBC, Volume III, Chapter 5). Fuel systems shall be shut off upon activation of the fire extinguishing system.

✔ An exhaust system is required in electrical equipment rooms where significant heat is generated by electrical equipment such as transformers.

✔ Capacity of range hood fans should be approximately 100 cfm per square foot of hood area or as recommended by an approved manufacturer. Where two-speed fans are used, two-speed make-up fans that are interlocked at both speeds are recommended. Exhaust air should be discharged straight up all the way to the roof or appropriate clean-out doors provided in the exhaust duct if turns are made.

✔ Exhaust canopy hoods and fans should be installed over kilns. The hood should be no more than two feet above the kiln. Adequate makeup air should be provided for the air that is exhausted to the outdoors.

✔ A manually controlled emergency exhaust system shall be provided for each chemistry and physical science room.

<u>Controls</u>

✔ Specifications shall contain a detailed written sequence of controls.

✔ Drawings shall include a control diagram and the corresponding written sequence of operation or just a detailed written sequence.

✔ Controls, starters, switches, etc. should be permanently labeled after installation.

✔ Rigid guards of cast iron or similar construction should protect thermostats or other vulnerable control items exposed in gymnasiums, locker rooms, shops, corridors, toilets, and unsupervised areas. Thermostat locations should be shown on plans.

✔ Control circuits for any type of space-heating device or water heater should be phase-to-ground, 120 v or 24 v. Phase-to-phase circuits are not acceptable.

✔ To conserve energy, clock and night set-back controls should be provided for space-heating and cooling equipment and exhaust fans. Use the building energy management system, when available.

✔ In most instances, cooling equipment should be turned off altogether during periods when buildings are unoccupied, unless needed for humidity control or to prevent freezing of water systems.

✔ Boiler systems should be designed and controlled in such a manner as to use the least amount of fuel possible in off-heating periods.

Commissioning

✔ Properly balanced air and water systems should be specified and proper installation should be assured by the designer.

✔ Thorough orientation and training on the operation of the system should be provided for the maintenance staff.

✔Piping system cleaning, treatment, and placement into service should be clearly specified and witnessed by the designer.

✔ Every effort should be made by the designer to assure that the fresh air quantity is set properly and that the school maintenance director/administrator is made aware that, if set too high, operating costs will be high and, if set too low, IAQ problems may result.

PLUMBING

General

✔ Plumbing plans shall bear the seal of the engineer responsible for their design, who is required to issue a certificate of compliance upon completion of the project (GS 133-1.1).

✔ Fire walls shall be shown on the plans.

✔ A complete summary of new and existing plumbing loads, in fixture units, shall be shown on the plans.

✔ Record drawings should be provided to the owner at the completion of the project. This service is usually not covered in the AIA standard contract and will need to be added.

✔ Provisions related to accessibility for the physically handicapped and applicable to plumbing systems can be found in the NCSBC, Volume I-C.

Drain, Waste, and Vent Systems

✔ Piping shall be cast iron, PVC, or other approved pipe.

✔ Floor drains shall not be installed in food storage areas.

✔ Floor drains shall be provided for boiler rooms and for mechanical equipment rooms that contain equipment such as cooling coils and water or steam piping systems.

✔ Floor drains of not less than three inches in size should be installed in all toilet rooms containing more than one flushing fixture (NCSBC requires drain for three or more flushing fixtures) and wherever water heaters are located. Floor drains may be excluded for under-counter water heaters where there is provision for proper disposal of relief valve discharges. Infrequently used drains should have traps resealed by waste from clear-water fixtures or be provided with trap primers. Provision should be made for the resealing of floor drain traps in spaces used as return air plenums, and four-inch minimum drains with sediment strainers are recommended.

✔ Acid-resisting waste lines (polypropylene or glass) shall be required for chemistry laboratories in high schools and are recommended for instructor stations in middle school science labs, but are not generally considered necessary for other laboratory areas. Corrosion-resistant traps or diluting drum traps are required on all fixtures in chemistry labs and may be considered for other labs, such as physics or biology.

✔ Plaster or interceptor traps are recommended for work sinks in areas such as art classrooms.

✔ Vent piping shall be a minimum of two inches in diameter at roof penetration.

✔ Cleanouts in horizontal pipe runs should utilize long-sweep quarter-bends or fittings providing one-eighth turn. Standard quarter-bends should never be used.

✔ Roof drainage shall be designed, as a minimum, in accordance with the NCSBC, Volume II.

✔ For interior roof drain systems, drains and flashings should be furnished and installed by the general contractor and piping should be installed by the plumbing contractor.

✔ In the expansion of waste systems that currently have terra cotta pipe, existing pipe should be replaced with PVC, cast iron, or other approved pipe.

✔ Water fountains shall not be located in areas with wood floors, such as gymnasiums and performing arts classrooms.

✔ Two well-separated floor drains should be provided in gymnasium laundry rooms.

Sewage Disposal Systems

✔ Locations and invert elevations of connections to public sewer systems shall be shown on plans (GS 130-13).

✔ Where a new on-site sewage treatment plant or an addition is required, the following apply.

- For plants that discharge to the land surface or surface waters and for ground absorption systems, application shall be made to DENR for approval of the new or existing site and proposed system and plant.

- DENR shall be consulted prior to the procurement of a site where on-site treatment or disposal is proposed.

- Plans and specifications for proposed new treatment plants or additions should be prepared according to DENR recommendations and submitted for their approval.

- Plans for treatment plants shall include complete details and elevations of all units and appurtenances, to include profiles from buildings to final point of disposition.

- Exclude garbage grinders and disposals from all kitchen designs where on-site wastewater treatment systems are used.

- Approval must be obtained from DENR to expand any school building that uses on-site wastewater treatment.

✔ Plans for all work must clearly indicate whether disposal is to a municipal or an on-site system.

✔ Where disposal will be to a municipal system, confirm that the system can accept the additional load.

✔ Plans shall provide profiles of sanitary sewer lines between manholes.

Grease Traps

✔ Waste from food disposal units shall not pass through grease traps.

✔ Interior grease traps shall not be used.

✔ Exterior grease traps shall be installed where applicable for the containment of grease waste from kitchens. A standard tank approved by DENR (1000-gallon minimum) is required.

Water Supply Systems

✔ Well sites shall be approved by the Division of Health Services of the DENR. Wells shall be located away from possible sources of contamination and properly protected. Well sites shall be shown by areas, rather than by specific locations.

✔ Where well-water systems are proposed, owners, engineers, and architects should consult the Division of Water Quality of the DENR for geological data.

✔ Plans shall show the well location and complete details of the well supply system, to include the well, pump, pump house, piping, and storage tank. If a pressurized storage tank exceeds 120 gallons nominal capacity, it shall be of ASME construction and shall be registered with the National Board (NCBPVR). When an elevated tank is installed, a fire hydrant shall be properly located on the site or a hose connection shall be provided on the standpipe, or both. With any type of on-site supply system, reasonable and appropriate fire protection equipment should be installed. When new well supply systems are used, provision for continuous chlorination is mandatory.

✔ If water is to be obtained from a public system, plans shall show the location and size of the supply connection and the size of the meter. Pressure-reducing stations should be used where supply pressure exceeds 80 psig.

✔ Water supply systems shall be disinfected before being placed in service (NCSBC, Volume II, Section 601).

✔ The engineer shall designate the water supply source and the size of existing pipes on the plumbing drawings.

✔ Domestic water piping should not be routed below slab-on-grade construction, where it can be avoided.

Hot Water Heating

✔ Dish washing and showering comprise the largest demands on water-heating equipment. These two water-heating demands should be generated and controlled separately. Kitchen hot water demands require a minimum of 140-degree water and should supply only the kitchen. Other small hot-water requirements may utilize electric water heaters. All water heaters should be placed where the components can be easily maintained.

✔ If tempering valves are used, they should be located in mechanical rooms that are as close as possible to the points of use.

✔ 180-degree water heaters should carry the NSF label, or equal (NSF Standard 5). If oil-fired heaters are used, the design shall ensure that there will not be a dip below 180 degrees in the supply temperature during a purge cycle.

✔ Sanitizing hot water from water heaters to dishwasher booster heaters should be recirculated by pumping to maintain maximum temperature at boosters.

✔ Water heaters and storage tanks shall have safety valves sized and installed as required by the NCBPVR. Dip tubes shall also conform to the requirements of the NCBPVR.

✔ Hot water storage equipment shall have linings that prevent interior corrosion. Specifications may include one alternate bid for nickel-lined, copper-clad, or stainless steel that provides a 10-year, non-prorated warranty.

✔ Electric water heaters of all types shall conform to the NEC 422-14 and NCBPVR requirements for the UL label. Control voltage should be volts-to-ground, such as 120 v or 277 v. Water heaters should be controlled on an energy management system if their load is useful for demand load shedding.

✔ Circulators (pumps) for domestic hot water should be of all-bronze construction. Control should be by time clock and temperature or through the energy management system.

✔ Recirculate from the most distant fixture or group of fixtures. The smallest available re-circulation pump is usually sufficient. Consider low-flow fixtures, despite the corresponding longer hot water delivery time.

Valves and Fittings

✔ A hose bibb with removable handle or key-operated lock should be installed in any toilet having a floor drain. Hose bibbs should have a minimum floor clearance of 18 inches. Each fixture should have an individual water supply cut-off valve.

✔ Flush valves shall be equipped with vacuum breakers (NCSBC, Volume II, Chapter 6).

✔ In exterior installations, care should be taken to prevent freezing. Freeze-proof wall hydrants should be key operated.

✔ Hose bibbs and wall hydrants with hose threads shall have back-flow prevention devices (NCSBC, Volume II, Chapter 6).

✔ Lavatory waste fittings should be cast brass, as opposed to tube construction.

✔ Lavatories should be acid resisting and have rigid supplies. Beehive or grid-type strainers shall be used.

✔ Supply pipe, valves, and fittings that are concealed (e.g. beneath a counter top) need not be of the rigid type and need not be plated.

✔ Isolation valves should be placed in positions that will allow ease of servicing by those who maintain the system.

Plumbing Fixtures.

✔ Elongated bowls and open-front seats without covers shall be used for water closets.

✔ Fixture schedules on plans are sometimes incomplete. Trim should be specified completely to maintain high quality.

✔ Outside drinking fountains shall be frostproof, with all wastes carried to dry wells or storm drains. Dry wells shall be located at least 50 feet from water supply wells.

✔ Counter-top sinks should have ledges with holes to receive faucets. Faucets should not be mounted directly in counter tops.

✔ Water fountains should be located in gymnasium dressing rooms or outside in the corridor..

✔ Wall-hung urinals with shields are recommended.

✔ The maximum allowable flow rate for shower heads is 2.5 gpm (NCSBC, Volume II, Chapter 4). Other flow rates are specified in the Code.

✔ Locate toilets for students and teachers so that no person will have to travel more than 200 feet for access.

✔ Provide one shower per four persons in physical education at the time of the largest anticipated class.

✔ Minimum facilities shall be provided in accordance with the NCSBC, Volume II, Table 407 (effective January 1, 1996). Additional fixture requirements for schools can be found in paragraph 407.2.4.

Fixture Mounting Heights

Grades		Regular Fixtures	North Carolina Accessibility Code: *Volume 1-C*
Water Closets			
PreK-3	H/C	-	12"-15" Seat, 36" max controls
4-7	H/C	-	15"-17" Seat, 36" max controls
8-12	H/C	-	16.5"-19.5" Seat, 44" max controls
PreK-5		15" Seat	-
6-8		15" Seat	-
9-12		15" Seat	-
Urinals			
PreK-7	H/C	-	14" max rim, 36" max controls
8-12	H/C	-	14"-17" rim, 44" max controls
PreK-3		14"-17" rim	-
4-5		17"-20" rim	-
6-8		20"-24" rim	-

9-12		24" rim	-

Lavatories & Sinks

PK-K	H/C	-	No knee space required if 30"x48" side approach
1-7	H/C	-	31" max rim or countertop 24" min knee space
8-12	H/C	-	34"-36" max to rim or countertop 29" min knee space
PK-K		24" countertop	-
1-5		27" countertop	-
6-8		31" countertop	-
9-12		31" countertop	-

Water Coolers

PK-7	H/C	-	30" max spout height
8-12	H/C	-	36" max spout height
PK-3		27" spout	-
4-5		31" spout	-
6-8		34" spout	-
9-12		34" spout	-

Showers

K-5 Boys & Girls	50"-56 spray head	11"-17" high seat 36" AFF controls if 60" flexible hose*
6-8 Boys	72" spray head	17"seat height (code states 11"-17" through grade 7 and 17"-19" above grade 7) 36" AFF controls if 60" flexible hose*
6-8 Girls	60"-66" spray head	17"seat height (code states 11"-17" through grade 7 and 17"-19" above grade 7) 36" AFF controls if 60" flexible hose*
9-12 Boys	72" spray head	17"-19" seat height 36" AFF controls if 60" flexible hose*
9-12 Girls	66" spray head	17"-19" seat height 36" AFF controls if 60" flexible hose*
		*48" AFF spray head, if fixed

(Grade 7 is assumed to be age 12.)
(Grades 8-12 handicapped requirements are the same as for adults.)

Kitchen Plumbing

✔ A service sink or a receptor should be located in the kitchen area.

✔ A lavatory with a mixing faucet shall be provided in the kitchen area for hand washing and shall be located in accordinance with DENR.

Gas Systems

✔ Gas systems, whether for LP or natural gas, shall conform to the NCSBC, Volume VI.

✔ Special concern should be paid the following areas in the Code:
- Kinds and types of pipe that are acceptable for gas
- Allowable pipe installation methods with regard to routing, placement, special treatments, and valving arrangements

✔ Metal pipe--not tubing--should be used for gas systems. Welded joints for larger sizes are considered good practice.

✔ Where it is necessary to install gas pipe under a building floor slab, the piping shall be encased in wrought iron, PVC (schedule 40), or steel pipe. Casings shall be tightly and permanently sealed and vented to the outside of the building.

✔ A 100 psi air test, with soap solution applied to all joints, should be specified for all gas piping.

✔ Where applicable, the engineer should specify that a permit be obtained for the installation of gas appliances and that local inspection of the work be requested.

✔ In locating gas-fired water heaters, the engineer shall ensure that there will be adequate air for combustion and proper ventilation for the space.

✔ Gas piping to laboratory casework should have a shut-off valve located in a lockable panel or in a lockable section of the instructor table.

✔ Vent lines from gas-fired appliances and devices shall terminate outside the building.

STRUCTURAL

General

One serious mistake a design professional can make during the preliminary design phase is leaving consideration of the structural system until after the architectural design is finalized. The following guidelines are provided to assist in the provision of adequate structural designs for public school facilities.

Data and other content are for informational purposes only. Neither School Planning nor any of its data or content providers assume liability for errors or for any action taken in reliance thereon. All plans and specifications shall exhibit the engineer's seal, signature, and the date, as required by G.S.89C.

Related General Statutes

133-1 Employment of architects, etc., on public works when interested in use of materials prohibited.

It shall be unlawful for any architect, engineer, or other individual, firm, or corporation providing design services for any city, county, or State work supported wholly or in part with public funds, knowingly to specify any building materials, equipment or other items which are manufactured, sold or distributed by any firm or corporation in which such designer or specifier has a financial interest by reason of being a partner, officer, employee, agent or substantial stockholder. (1933, c. 66, s. 1; 1977, c. 730.)

133.1.1 Certain buildings involving public funds to be designed, etc., by architect or engineer.

(a) In the interest of public health, safety and economy, every officer, board, department, or commission charged with the duty of approving plans or specifications or awarding or entering into contracts involving the expenditure of public funds in excess of one hundred thousand dollars ($100,000) for the repair of public buildings where such repair does not include major structural change, or in excess of forty-five thousand dollars ($45,000) for the construction of or additions to, public buildings or State-owned and operated utilities shall require that such plans and specifications be prepared by a registered architect, in accordance with the provisions of Chapter 83 of the General Statutes, or by a registered engineer, in accordance with the provisions of Chapter 89C of the General Statutes, or by both architect and engineer, particularly qualified by training and experience for the type of work involved, and that the North Carolina seal of such architect or engineer together with the name and address of such architect or engineer, or both, be placed on all such plans and specifications.

(b) On all projects requiring the services of an architect or engineer, or both, the architect or engineer, or both, whose names and seals appear on the plans and specifications shall conduct frequent and regular inspections or such inspections as required by the contract and shall issue a signed and sealed certificate of compliance to the awarding authority that:

(1) The inspection of the construction, repairs, or installations have been conducted with the degree of care and professional skills and judgment ordinarily exercised by a member of that profession; and

(2) To the best of his knowledge and in the professional opinion of the architect or engineer the contractor has fulfilled the obligations of such plans, specifications, and contract.

No certificate of compliance shall be issued until the architect and/or engineer is satisfied that the contractor has fulfilled the obligations of such plans, specifications, and contract.

(c) The following shall be excepted from the requirements of subsection (a) of this section:

(1) Dwellings and outbuildings in connection therewith, such as barns and private garages.

(2) Apartment buildings used exclusively as the residence of not more than two families.

(3) Buildings used for agricultural purposes other than schools or assembly halls which are not within the limits of a city or an incorporated village.

(4) Temporary buildings or sheds used exclusively for construction purposes, not exceeding 20 feet in any direction, and not used for living quarters .

(d) On repair projects involving the expenditures of public funds in an amount of one hundred thousand dollars ($100,000), or less, or on construction or addition projects involving the expenditures of public funds in an amount of forty-five thousand dollars ($45,000), or less, and on which no registered architect or engineer is employed, the governing board or awarding authority shall require a certificate of compliance with the State Building Code from the city or county inspector for the specific trade or trades involved or from a registered architect or engineer, except that the provisions of this subsection shall not apply on projects wherein plans and specifications are approved by the Department of Administration, Division of State Construction, and the completed project is inspected by the Division of State Construction.

(e) All plans and specifications for public buildings of any kind shall be identified by the name and address of the author thereof.

(f) Neither the designer nor the contractor involved shall receive his final payment until the required certificate of compliance shall have been received by the awarding authority.

(g) On all facilities which are covered by this Article, other than those listed in subsection (c) of this section and which require any job-installed finishes, the plans and specifications shall include the color schedule. (1953, c. 1339; 1957, c. 994; 1963, c. 752; 1973, c. 1414; s. 2; 1979, c. 891; 1981, c. 687; 1983 (Reg. Sess., 1984), c. 970, s. 1.)

<u>133-2</u> Drawing of plans by material furnisher prohibited.

It shall be unlawful for any architect, engineer, designer or draftsman, employed on county, State, or city works, to employ or allow any manufacturer, his representatives or agents, *to write, plan, draw, or make specifications for such works or any part thereof. (1933, c. 66, s. 2.)*

133-3 Specifications to carry competitive items; substitution of materials.

All architects, engineers, designers, or draftsmen, when providing design services; or writing specifications, directly or indirectly, for materials to be used in any city, county, or State work, shall specify in their plans the required performance and design characteristics of such materials. However, when it is impossible or impractical to specify the required performance and design characteristics for such materials, then the architect, engineer, designer, or draftsman may use a brand name specification so long as they cite three or more examples of items of equal design or equivalent design, which would establish an acceptable range for items of equal or equivalent design. The specifications shall state clearly that the cited examples are used only to denote the quality standard or product desired and that they do not restrict bidders to a specific brand, make, manufacturer or specific name; that they are used only to set forth and convey to bidders the general style, type, character, and quality of product desired; and that equivalent products will be acceptable. Where it is impossible to specify performance and design characteristics for such materials and impossible to cite three or more items due to the fact that there are not that many items of similar or equivalent design in competition, then as many items as are available shall be cited. On all city, county, or State works, the maximum interchangeability and compatibility of cited items shall be required. The brand of a product used on a city, county, or State work shall not limit competitive bidding on future works. If an architect, engineer, designer, draftsman or owner prefers a particular brand of material, then such brand shall be bid as an alternate to the base bid and in such case the base bid shall cite three or more examples or items of equal or equivalent design, which would establish an acceptable range for items of equal or equivalent design. Substitution of materials, items, or equipment of equal or equivalent design shall be submitted to the architect or engineer for approval or disapproval; such approval or disapproval shall be made by the architect or engineer prior to the opening of bids. The purpose of this statute is to mandate and encourage free and open competition on public contracts. (1933, c. 66, s. 2; 1951, c. 1104, s. 5.)

133-4 Violation of Chapter made misdemeanor.

Any person, firm, or corporation violating the provisions of this Chapter shall be guilty of a misdemeanor and upon conviction, license to practice his profession in this State shall be withdrawn for a period of one year and he shall be subject to a fine of not more than five hundred dollars ($500). (1933, c. 66, s. 4.)

Design and Detailing

Major structural elements, such as columns, beams, trusses, retaining walls, lateral braces, moment frames, shear walls, structural floors, roof decks, footings, and piers should be designed and detailed adequately for varying conditions. Minor structural elements, such as slabs on grade, low retaining walls, lintels and exterior wall openings often get little or no design and are inadequately detailed. Joint locations and joint types are likely to be left to the contractor. The engineer representing the owner should include complete details on the drawings to ensure that the contractor knows what is intended.

Specifications

Inadequate specifications generally fall into one of two categories--incomplete and unrealistic.

Incomplete specifications fail to spell out requirements adequately. An example is failure to require air entrainment in concrete that will be exposed to freezing and thawing. Another form of incomplete specification is stating, "Concrete work shall conform to the requirements of ACI301." Such a requirement is good, but without listing all the supplemental requirements, it is incomplete.

Unrealistic specifications include those that call for tolerances either closer or greater than are really needed and those that require strengths too low to ensure proper performance. Overly-strict specifications can increase initial costs needlessly, while those that are not strict enough can result in long-term maintenance and repair costs that exceed initial savings.

Inspection and Control Effective inspection not only helps the owner get what has been specified, but helps the contractor avoid costly mistakes. The competent inspector understands which items are important and the need to be present at critical times during a project, and doesn't waste time nit-picking items that have no bearing on project quality. Instead, direction is provided to the adjustment or correction of significant out-of-specification materials and procedures.

An excellent way to minimize future repair costs is to take steps to assure the desired quality as the structure is built. Beginning with the design and detailing of the project and continuing through inspection and control, quality control of sensitive aspects of the construction procedure should be considered and emphasized.

Acceptance of Structural Members Structural members delivered to the field that are not manufactured in accordance with the plans and specifications and with code standards should be rejected. Field modification to any structural member should not be permitted. Damaged members should not be used and should be returned.

Soil/subsurface Investigation The nature of the soils underlying a building has a very important influence in determining the type and size of the building's foundation. As a result, construction costs are significantly affected by the types of soil on which the building is to be built. Foundation type and size affect construction time for the foundation and may therefore have a significant effect on the construction schedule for the entire building. Because of the pervasive influence of soils on building design and construction, it is highly desirable before a site is purchased that at least some knowledge of the subsurface and surface conditions be obtained and interpreted for the owner by a competent soil engineer.

Wind Loads

✔ Calculations of wind loads shall be based on the provisions of ASCE 7-93.

✔ To determine the wind pressure on a structure, consider the following:

A. Main wind-force-resisting system: At least two directions (sets) of wind loads need to be calculated--one parallel to ridge and one normal to ridge.
B. One set of force for components and cladding at different zones, regardless of wind direction.
C. Internal positive and negative pressures.

✔ Components and cladding: Structural elements that either are directly loaded by the wind or receive wind loads originating at relatively close locations and that transfer those loads to the main wind force-resisting system. Examples include curtain walls, exterior glass windows and panels, doors, roof sheathing, purlins, girts, studs, rafters, and roof trusses.

✔ Main wind-force-resisting system: An assemblage of major structural elements assigned to provide support for secondary members and cladding. The system receives wind loads primarily from relatively remote locations. Examples include rigid and braced frames, space trusses, roof and floor diaphragms, shear walls, and rod-braced frames.

Foundations

✔ A foundation design should be based on a subsurface investigation report.

✔ Avoid designing two or more foundation systems for the same building.

✔ It is advisable to assign fill control testing and inspection work to the same geotechnical firm responsible for the subsurface investigation and recommendations.

✔ The subsurface investigation report should be included in the specifications.

✔ Always place the bottom of the footing below the frost line.

✔ Lower column footings at roof drain leaders.

✔ Specify drainage fill and drainage tile behind basement walls and retaining walls.

✔ The bottom of a footing for a new wall or column should at least match the elevation of the bottom of existing wall or column footings. In most cases, soil around existing footings is loose backfill.

Slabs on Grade

✔ Typical slab-on-grade construction will comprise a four-inch to five-inch (4-5") thick concrete slab with adequate welded-wire fabric (W.W.F.) on a four-inch (4") gravel base on vapor barrier.

✔ Steel reinforcement should be placed on supports one-third the depth from the top of the slab or to provide a minimum of two inches (2") of concrete cover.

✔ There is no equivalent substitute for steel reinforcement in a slab. Steel can reduce random cracking; reduce and control crack width and help to maintain aggregate interlock; prevent the slab from settling or displacing; increase strength and provide reserve strength subsequent to cracking; and provide cost savings over the life of the slab.

✔ While admixtures, such as fibermix, that can reduce the formation of plastic shrinkage cracks and provide greater impact resistance in a slab may be used along with steel reinforcement, they should not be considered a substitute for steel reinforcement.

✔ Floor slab joint controls should be provided at a maximum of thirty feet (30') in any direction. The area within control joints should be as square as possible. Joints should also be provided at columns and wall junctures.

Floor Construction

✔ Typical suspended structural floor construction comprises a five-and-one-half inch (5 ½") total slab thickness with a two-inch (2"), 20-gage composite metal deck, and a span of approximately eight feet (8'-0") o.c. on steel beams.

✔ Check the following items for composite beams with formed steel deck:

A. Slab thickness above deck (minimum of 2")
B. Shear connectors (maximum diameter: 3/4"; minimum length after welding: 1 ½" above rib)
C. End reactions must be calculated and shown on the drawings
D. Shoring requirements

Roof Construction

✔ In general, the roof deck serves two primary functions--structurally to transfer the live and dead loads to supporting beams, joists, and purlins and the lateral forces to the vertical structural bracing members; and, to serve as a base to which the roof insulation and membrane are attached.

✔ Typical structural roof decks used for schools include:

A. Steel: 1 ½" narrow, intermediate, or wide rib (22 gage)
B. Tongue-and-groove wood plank or structural plywood
C. Lightweight insulating concrete decks and fills (cementitious)
D. Gypsum concrete on forms
E. Standing-seam with 1 ½" sub-deck

✔ The type of roof deck and roof deck anchorage system should be specified.

✔ Use the diaphragm capacities of a roof deck to transfer lateral force; otherwise, a structural mechanism, such as horizontal trusses, should be employed to transfer lateral forces to designated vertical structural bracing members.

✔ When a standing-seam roof system is specified, employ a roof deck with adequate diaphragm capacity to go with it.

✔ Specify roof deck anchorage appropriate for the wind zone.

✔ Lifting and peeling: When perimeter flashing assemblies are inadequately secured, wind uplift forces can remove them and leave the edges of the roof unprotected. Covering, unless well secured, may then be peeled back from the edge and fail. Wind pushing against the covering will cause more of the material to be peeled off, moving the failure inward. In high wind areas, at the perimeter of the roof and at expansion joints, the following are recommended:

A. Attach the "2x" wood plates to the structural members with bolts.
B. In addition to mechanical fasteners, glue the membrane to the wood plate.
C. Secure flashing assemblies at a maximum of from 4" to 6" o.c.
D. Construct a perimeter parapet wall.

✔ Whenever possible and practical, the slope required for roof drainage should be incorporated into the structure to effect initial and replacement cost savings.

✔ Roof slope to drains should be at least 1/4" per foot. There should be no standing water on a roof deck 48 hours after it ceases raining.

✔ When computing slope, consider deflection under live and dead loads.

✔ Roofs work best when their geometry is simple. Any interruption of the roof's continuity, such as clerestories, roof monitors/skylights, multiple hips, valleys, and wall and expansion joint flashings will complicate roof structure and can lead to leaks and higher maintenance costs.

✔ Any proprietary roof or building system should be bid as an alternate to a non-proprietary base bid system (G.S.133-3).

✔ Roof deck capacities should be specified that support loads required by code, plus an additional 10 psf to cover possible future increases in dead load. A minimum 22-gage thickness with a maximum five-foot (5') span is recommended.

✔ Pull-out tests for mechanical fasteners are required on concrete and cementitious filled decks.

✔ Consider the following when using cement fiber roof decks:

A. End joints must occur above supports unless bulb tees are specified.
B. The diaphragm action of the deck
C. Joints must be tight.

✔ Provide 2"x 4" wood at each rib under curb for roof mechanical unit sitting on a metal deck.

✔ When using a composite metal roof deck system, be aware of the composite action between separate materials and provide a positive nailable material.

✔ Should a complete removal of roofing material from a composite metal deck include replacement of some of the metal decking, replacement decking should be of the same material to prevent structural deficiencies.

✔ Avoid specifying loose-laid ballasted (gravel size of 3/4" to 1 ½") roofing systems at or near high-wind locations. Rocks can become destructive missiles in high winds.

✔ Roof expansion joints should always be provided at the following locations:

A. Where expansion or contraction joints are provided in the structural system
B. Where steel framing, structural steel, or decking change directions
C. Where discontinuity in a structural deck occurs
D. Where deck type changes (e.g. where a plywood deck and a steel deck abut)
E. At junctions where interior heating conditions change, such as a heated office abutting an unheated warehouse)
F. Where movement might occur between vertical walls and the roof deck

✔ Expansion joints may be ineffective where they are not continued through the remainder of the structure.

✔ Expansion joints and area dividers should be elevated a minimum of eight inches (8") above the plane of waterproofing membrane.

✔ Roof collapses can occur due to rain or wet snow loading on flat roofs with slopes of 1% or less, roofs of lightweight construction, and roofs designed for minimum live loads. Collapse may also occur with rain overloading caused by inadequate interior drains or perimeter scuppers, rainfall intensities that exceed design expectance, clogged drainage devices, and backed-up storm drainage systems. Roof scupper height should be specified to ensure that no more than six inches (6") of water can accumulate at the drain inlet level, should the drain fail to work.

✔ The weight of drifting snow is critical to the design of a new roof to reduce its collapse potential and in estimating the collapse potential of an existing roof. Three common roof shapes--multi-level, curved, and valley--are subject to snow drift build-up. One cubic foot of snow can weigh about 14 pounds and wet snow can weigh about 21 pounds per cubic foot.

Steel Joists

✔ Manufacturers' calculations for load-carrying capacities of joists consider only the uniformly distributed vertical loads in the plane of the joist--not any concentrated loads, lateral loads, or any loads acting outside the plane of the joist. Open-web steel joists are not recommended for carrying bi-axial bending.

✔ Joists should be spanned in the direction of the roof slope, if possible.

✔ If joists are spanned at right angles to the roof slope, the engineer of record should provide design calculations that address all sizes of joists spanning various distances for different conditions. Where any loads hang from the bottom of joist chords, special attention and calculations are required.

✔ A row of bolted bridging is required at or near mid-span for joists 40' or longer.

✔ When cross-bridging is specified, horizontal bridging units should be used in the space adjacent to the wall to allow for proper deflection of the joist nearest the wall.

✔ Check minimum depths required for sloping bearing seats.

✔ Where uplift forces due to wind are a design requirement, specify uplift bridging near the first bottom chord panel at each end of the joist.

✔ OSHA safety standards for steel erection require that open-web steel joists on or near column lines be bolted for erection safety.

✔ Where bottom joist chords bear on masonry walls, force transfer mechanisms should be specified to stabilize the joists at bearing and to bring the diaphragm force from the roof deck down into the wall.

✔ Load diagrams should be provided for special loading conditions.

✔ Field modification of joists or joist seats should not be allowed.

✔ Bottom chord extensions of joist girders should not be welded to stabilizer plates (6"x6"x3/4" plate minimum) unless the design requires use of joist girders as moment resistive frames.

✔ When using joist girders as moment resistive frames, design connections and columns in accordance with loading conditions.

✔ Minimum depth of joist seats should be specified.

Masonry

✔ Bond beams and masonry wall corner reinforcement should be specified, and horizontal masonry ties should be provided at wall intersections.

✔ Control joints should be specified near corners and at exterior wall openings (on both sides if an opening is wider than ten feet (10'). Space between control joints should be no greater than 25' on exterior walls and 40' on interior walls. Control joints should be detailed.

✔ Reinforced masonry piers that support roof structure should be identified and dimensioned on foundation plans.

✔ Lintel schedules, with bearing lengths and details, should be provided on plans.

✔ Weep holes above finish grade should be specified.

✔ Minimum seismic reinforcements should be specified and designed as required.

✔ Provide close field supervision to construction of reinforced masonry piers and pilasters.

✔ Provide adequate lateral supports for masonry walls to ensure code and performance compliance.

✔ Vertical reinforcement extended into the bond beam at the top of a wall should have a 90-degree hook in high wind areas. Cells at reinforcement should be filled with 3,000 psi pea gravel concrete.

✔ Steel columns are recommended in lieu of reinforced masonry piers to support main roof beams and trusses because they:

A. Clarify the geometry.
B. Provide positive support.
C. Present fewer field control problems.
D. Eliminate the potential for improperly located reinforcement in masonry piers.
E. Minimize masonry wall cracking at pilasters.

Framing Systems

✔ Complete structural connection details that include gusset plate sizes, length and size of welds, and numbers and sizes of bolts should be provided.

✔ The tops of steel elevations should be noted on framing plans.

✔ Design and provide, for all roof trusses, configurations that show bearing locations and member sizes and specify force for each member.

✔ Bottom chords of roof trusses should not attach to non-load-bearing interior walls.

✔ Properly flag section cuts on framing plans.

✔ Indicate all structural components on framing plans, clearly defining shear walls, moment frames, and both vertical and horizontal diagonal braces used to stabilize the building.

✔ All steel members exposed to weather should have hot-dipped galvanized coatings. "Weathering" steel should not be used.

✔ Connections:

A. Beam-to-beam connections should develop half the total uniform load capacity for the given section and span.
B. Cantilevered beam connections should develop the total capacity of the beam in both shear and moment.

✔ Designs for folding partition supports should take into account the weight of the partition when gathered at the ends and provide adequate lateral bracing to accommodate it.

✔ For quality and vibration control, composite floor construction is recommended.

✔ Deflection limitation is L/360 for metal wall cladding and L/600 (or less than 3/8") for brick facing.

✔ Exterior stud walls serve a structural function. Design and detail studs, tracks, bridging, and connections. Provision for jambs, heads, and sills at exterior stud wall openings should be specified.

✔ A bracing frame system should be designed for roof trusses to provide stability during steel erection and for the completed structure.

✔Demolition of structural members should not be left solely to the contractor. Where the design for demolition or renovation of existing buildings involves replacing or removing structural members, the method for their removal and for the shoring of remaining structural members should be detailed on the contract documents.

✔ Vertical slotted holes should be used for the connection between steel perimeter beams and exterior walls to allow deflection of beams under load. Locate connections for easy visual field inspection.

✔ Stair details should be shown on structural drawings; there may be many unusual structural problems for which the structural engineer is responsible.

Pre-engineered/modular Building Systems

✔ Pre-engineered structures or systems, such as metal building systems, modular building components or systems, and grandstands or bleachers, that are used for school projects are subject to design review by School Planning.

✔ Conditional certificates of review may be issued on partially completed structural designs that include general layouts and other information necessary to conduct reviews. Such certificates allow mobilization and site preparation to commence prior to completion of final structural designs.

✔ Project reviews are completed and certificates of review issued upon certification to School Planning that foundation and other structural systems have been designed by or reviewed and approved by structural engineers for the projects.

✔ G.S.133-1 requires that project architects and engineers be in the employ of owners and prohibits project designers being employed by or having financial interest in manufacturers or suppliers of pre-engineered structures.

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