

SAFETY IN CONSTRUCTION

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SYNOPSIS

This paper discusses different stages and activities involved during the process of a project construction. The paper focuses on human as well as technical errors leading to structural and component failure which can occur at each stage in the progress of work from design, material of construction, erection, commissioning to its execution. This paper also deals with safety standards, civil codes essentially required for a project, and site-safety measures to be borne in mind for construction safety during project execution. Listed incidents occurred at construction sites amply convince of necessity of safety all the time as work progresses. The alertness about safety from conceptual to engineering stage enhances the intrinsic safety of the installation.

INTRODUCTION

Safety in construction is to be ensured by careful planning of the location, design and lay out of the project. Numerous accidents are reported as no suitable measures are taken initially at planning stage.

Construction of industrial structure requires adherence to statutes and codes prescribed for safe job practices. For this, the Company and the contractors must be in harmony to establish inter-relationship between statutory requirement and practical approach. The company must insist upon compliance with the provisions of safety and health regulations that pertain to the related construction work.

Along with codes and standards, thorough supervision by a competent person is a must to work without incidents. Hence, with conception of any project, it is of a paramount importance that due care is taken in construction safety.

PROJECT CONSTRUCTION

STAGES

Human or engineering errors leading to structural failure can occur at each stage in the progress of a component, a plant or a structural from design to the end of commissioning

and operation. A convenient starting point is obviously to consider the conventional basis of design for adequate strength.

The individual stages during process of a project construction of a chemical plant can be classified as shown in the Figure (1).

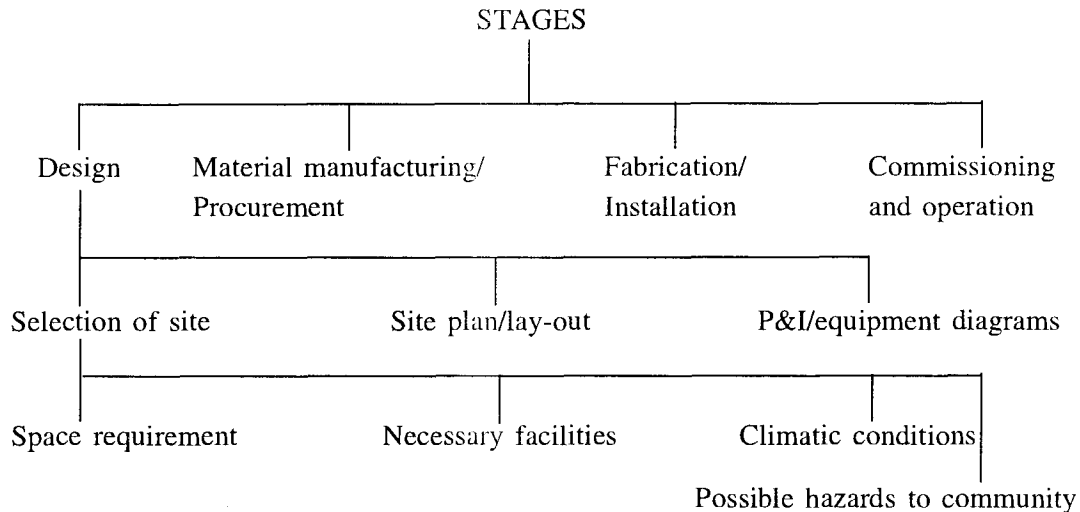


Fig. 1. Different stages during process of a project construction.

Creeping in any of the stages may result in structural failure.

DESIGN

To ensure that the designs are strong enough to withstand the rigors of service conditions the designer needs to know:

- The expected loading history in service
- The expected environmental conditions

This is to be given a prime importance while carrying the following activities (2):

- Selection of site
- Site plan / lay-out plan
- Piping and instrument / equipment diagrams

SELECTION OF SITE

While selecting a site the following factors are considered:

- Space requirement

- Necessary facilities (water, electricity, transportation, labor supply etc.)
- Climatic conditions
- Possible hazards to community

The unit requirements should not be adjusted as per the availability of space or network of piping. Equipment should not be so located that filling of confined space occurs when one enters a plant. Such crowding and the resulting congestion of buildings and other facilities leads to increased hazards. The size of the site is determined by present space requirements and possible future expansion.

Plans should include all necessary safety precautions such as

- Minimum distances between manufacturing and storage facilities
- Minimum distances from adjoining property
- Well located waste disposal areas
- Drainage system and
- Outside facilities

CLIMATIC CONDITIONS

Climatic condition of the area is one of the important factors. Prevailing wind and its velocity may determine the best location of process unit and administrative building. While selecting the site, civil engineering should take care of such forces. Civil engineering code indicates thickness and height of walls which withstand specific wind loads while unsupported. Wind velocities can be withstood with the help of wall made from concrete blocks of varying height.

Plans and specifications should include protective measures for personnel considering the eventualities like a hurricane, tornado, earth quake or flood area and safety factors must be designed accordingly into the operation.

POSSIBLE HAZARDS TO COMMUNITY

The plant, component or a structure proposed for construction, should not pose a hazard to community when it comes in service. So, in design stage itself due consideration should be given on following aspects:

- In-built safety in the system
- Adequate safety measures
- Pollution monitoring system
- Risk assessment

PLANS AND DIAGRAMS

While preparing site plan/lay out, piping and instrument/equipment diagrams the safety codes and statutory requirements are considered.

MATERIAL OF CONSTRUCTION

The following materials are used to fabricate vessels, tanks etc.

- Mild steel
- Mild steel with rubber lining
- Mild steel with stainless steel cladding
- Stainless steel
- Aluminum
- Carbon steel etc.

Material for vessel and tanks is selected so that it should withstand different forces applied and should not create any hazards when in use. In calculations, generally the ductile failure is considered. At the same time, long storage at high temperature, stress fluctuation, sudden release of temperature and corrosion attacks should be considered to avoid creep failure, brittle failure, metal fatigue and corrosion respectively.

FABRICATION AND INSTALLATION

The foundation work and welding to structure these are the two jobs being carried out in fabrication and installation stage. Foundations are based on civil engineering norms. Welding being a skilled job, requires a competent person.

The compliance of safety codes/standard and the requirements given under statute is mandatory in this stage.

The codes and standards followed are given below.

- Bureau of Indian Standard
- British Standard
- National Fire Protection Association
- American National Standard Institute
- Tariff Advisory Committee Manuals

COMMISSIONING AND OPERATION

Commissioning stage is the final stage of a project. Before handing over to operation, safety audit is to be carried out.

At this stage safety audit is inevitable state to ensure nothing is left unattended.

This method brings out design faults, wrong selection of material of construction, violation of safety codes/standards and locate important unsafe conditions of following nature.

- No access to movement
- No access for operation
- Vents are not connected to scrubber system
- Vents are not located at safe place
- No provision to collect/drain spilled material
- Floor grating not tagged properly
- No detectors provided
- No instruction boards displayed
- Fire fighting arrangement is not as per TAC norms
- No color code followed
- No flow direction markings on valves
- No proper labeling of tanks
- No guards provided
- No proper earthing provided

ACCIDENTS AT CONSRUCTION SITE

- Placing of AC sheets on the roof was in progress. Two labourers having safety belts were on the job. Suddenly one of the labourer loosing balance fell down from the height of 15 m and sustained multiple injuries.

Remedial Measures:

When the safety belt got jerk its rope broke from the centre. To avoid the falls from height, BIS mark safety belts should be used.

- A welder was doing welding work on the height of about 20-m. He got shock and fell down on the ground and received multiple injuries.

Remedial Measures:

Electrical supply for welding machine should not be taken with bare wire and earthing is to be given to job only. The recommended procedure is, electrical supply should be taken with plug-pins only.

- To lift the material at third floor to cast a slab, the arrangement of H-frame and skip hoist was made. While taking trial of skip hoist by putting empty bucket on it, the bucket tilted by a jerk and came out from the bracing of H-frame, got bounced and fell on the mixture kept on the ground and in turn hit a labourer working near mixture.

Remedial Measures:

Civil engineering must be considered while erecting a skip hoist.

The bracing placed on H-frame should not have gaps than required.

The bucket should be secured on trolley with chain provided for the purpose.

- A pit was constructed at site to store water. In the night a child labourer drowned in the water.

Remedial Measures:

The open pit and gaps on the floor should be barricaded by providing railings. Child labourer should not be employed.

- Construction work was in progress. Some labourers were working on height. The supervisor passing below got hit by falling mild steel rod and collapse there itself.

Remedial Measures:

Area below such work should be cordoned off. All persons working at site should wear required personal protective equipment such as helmets, safety shoes, safety goggles, face shields, safety belts etc.

- In the plant building a gap was kept open at second floor to install the reactor. A person just passing through that location was obstructed with the projected object and loosing balance fell down on the ground from the gap. He died on the spot.

Remedial Measures:

The open pit and the gaps on the floor should be barricaded by providing railings.

- Water proofing work was in progress on the slab of a laboratory building. A mason by bending and moving backward was doing surfacing with the help of aluminium trowel. Unaware of the end of slab, he obstructed with 6” parapet wall and loosing balance fell down on head and as a result got major head injury (3).

Remedial Measures:

One should be attentive of risks while on job.

Following are few accidents taking place at construction site because of other unsafe practices also.

- 150 lb. crane hook failed.
- Wire ropes broken under tensile load in excess of its strength. Deformed into a curl as it bent around a round shaft.
- Fatigue break because of maximum service, etc. (2).

There are some accidents reported because of design fault. Two cases are given below,

1. Suspended catalyst was removed from a process stream in a pressure filter. When filtration was complete, the remaining liquid was blown out of the filter with steam at 2 Kg. Pressure. Pressure in the filter was blown off through a vent valve. The operator then opened the filter for cleaning by opening the filter door. As soon as he opened it, it blew open and the operator crushed between the door and part of structure resulting into his death (4).

Remedial Measures:

In design itself the interlock should be provided so that vessel cannot be opened until the pressure is released.

2. Glycerol was placed in a reactor and circulated through a heat exchanger. When temperature reached to 115°C, addition of ethylene oxide was started.

Reaction is exothermic; exchanger now used as cooler. The temperature is maintained between 115°C and 125°C.

One day EO addition was started and suddenly pressure in the reactor rose. Operator adjusted trip setting to raise the temperature to 200°C; still pressure did not recede.

Then operator realised that the valve at the bottom of reactor was closed, so he opened it and explosion took place in the pump (5).

Remedial Measures:

Designer assumed that the temperature near the pump would be the same as that in reactor, and also assumed that if pump is energised, then liquid would circulate. But this will not be always the case. High-pressure trip is required.

3. Instruments places below eye level.
4. To repair a flow meter, a man had to walk six times from the orifice plate to the transmitter and back. To get from one to the other, he had to walk 45m, cross a 30-inch-diameter pipe by a footbridge and walk 45m back- a total of 540m for the whole job. Alternatively he could climb over the pipe (2).

Is it reasonable to expect a man to repeatedly walk 90m to avoid climbing over a pipe?

COMPLIANCE OF RULES

In exercise of the powers conferred by sub-section (3) of section 1 of the “Building and other Construction Workers (Regulation of Employment & Conditions of service) Act, 1996.

The central Government from March 1, 1996 brought in force a new Act to be implemented in whole of India.

Following are the important provisions given in said Act (6) -

- Fixing hours for normal working day
- First-aid
- Safety Committee & safety Officers
- Notice of certain accidents
- Safe means of access, safety of working place, work under supervision of competent person, adequate & suitable lighting at work place, the keeping of personal protective equipment, safe guarding of machinery, limits of weight etc.

SAFETY CODES

Some of the civil safety codes published by Bureau of Indian Standard are listed as follows:

- IS : 3696 Safety codes for scaffolds and ladder
- IS : 3764 Safety codes for excavation work
- IS : 4130 Safety codes for demolition of buildings
- IS : 4912 Safety codes for floor and wall opening, railing
- IS : 5121 Safety codes for piling and other deep foundation
- IS : 7205 Safety codes for erection of steel structural work
- IS : 8989 Safety codes for erection of concrete framed structures
- IS : 2750 Specifications for steel scaffolding
- IS : 4081 Safety codes for blasting and drilling operations
- IS : 7293 Safety codes for working with construction machinery
- IS : 0456 Design of RCC structures
- IS ; 0800 Safety codes for design of steel structures
- IS : 0875 Safety codes for structural safety of buildings
- IS : 1893 Criteria for earthquake design of structures

SAFETY MEASURES

When construction is being done, the employees and equipment should be protected from all construction hazards including open excavation, falling objects, welding operation, dusts, dirt, temporary wiring, temporary overhead electrical lines etc. Barricades, fences and guardrails should be set-up and appropriate warning signs should be posted. Night illumination should be provided in the areas where open trenches or ditches create hazards in walkways and roadways.

Care should be taken specifically to prevent trucks and other mobile equipments from colliding with each other, with pipelines, power lines and other equipment. Signalman should be posted to serve as an eye for truck drivers.

No one should be allowed to stand on the running board or bed of truck. Workers must not be permitted to ride on a loaded moving truck.

Modern construction requires machines like tractors and bulldozers for site operation, power shovel for excavation, cranes and derricks for placing structural members, concrete mixers, compressors, and generators. No such machine equipment should be placed in operation until competent person has inspected it and found to be in a safe operating condition.

Belts, pulleys, gears, chains, shafts, clutches, drums, flywheels and other rotating parts of equipment shall be guarded. No guards or safety appliances shall be removed or made ineffective. Current carrying parts of electrically operated equipment should be properly insulated or guarded. High temperature lines and equipment should be covered with suitable insulating materials.

Platforms, foot-walk, steps, ladders, handholds, guardrails and toe-boards should be installed on the equipment. Suitable operating floors or platforms, surface with slip-resistant material and gaps/opening on floors should be cordoned off. At the end of work, equipment should be set and locked. Safe load capacity and operating speeds should be pasted on all equipment.

Steel erection involves extensive use of cranes, derricks, hoists, ropes and slings. For lifting heavy loads, wire rope ceiling is preferable to chains. Operating with either chain or wire rope the manufacturer's capacity rating should not be exceeded. At point where rope ceilings pass round sharp corners, padding should be provided.

Airflow should be shut off and pressure released before pneumatic hand-tools are disconnected. When bolts are being knocked out, they should be retrieved so they do not fall on anyone below.

Impact wrenches should be provided with a locking device to retain the socket.

Welding is basically an uncontrolled heat treatment process. Welding or flame-cutting if not done properly it may result into -

- A brittle structure in the heat affected zone of the parent material
- Impurities in the zone of fusion
- Incomplete welding penetration and fusion
- Creation of residual stresses

Considering the above facts, a job of welding should be assigned to a competent person.

The worker at construction site should be equipped with necessary Personal protective equipment. Do not permit employees to work near electrical wires unless the wires are fully insulated. Do not allow employees to work on wet, freshly painted or slippery construction. Wherever it is impractical to provide temporary floor, suspend safety nets below points where employees are working. Where guy cables or braces are used to hold steel during erection, make sure they are guarded to prevent trucks or other equipment from being hooked into them. Makeshift methods and short cuts should be avoided while lifting, moving, and transferring machines and equipment. All "out of order" equipment should be shut down for repairs. Suitable sign should be posted and not removed until repair has been completed. Mobile equipment should, if possible be removed to a safe location. Equipment suspended in string or supported by hoist or jacks for repairs should be blocked before anyone is permitted to work underneath it. When repairs are carried out, remote from the source of power on equipment such as conveyors etc. use chains, blocking to prevent accidental start up. Before repair on electrically operated equipment begins; the main switch should be locked. The person doing the repair should retain the key to the switch lock. When using temporary heating equipment, assign a qualified employee for its operation and maintenance. To prevent injury during excavation work, think of adequate protective measures as a part of the job. Study pre-excavation conditions in order to evaluate changes that might occur, situation that might develop and to plan the job ahead. Excavated material should be placed at least 0.6m from the edge of the excavation unless toe-board or other barricades have been installed to prevent fallback. Excavation should be barricaded to prevent employees from falling into it. Keep warning sign. A trench of 1m or more deep should be provided with ladders. The ladders should extend from the bottom of the trench to at least 0.9m above the surface of the ground. Construction of all ladders should conform to BIS codes. A scaffold should be designed to support at least four times the anticipated weight of workers and material. A safe convenient means must be provided to gain access to the working platform level. Scaffolds should conform to the BIS codes. When work is continuing on the scaffolding, the area below it should be cordoned off. The hoist should be operated with limitation of specification prescribed by manufacturer for rated load capacity, operating speed etc. and instructions gone through to understand hazards.

RECOMMENDATIONS

Following are some important recommendations required to be considered for construction safety-

- Competent engineers in design, production or maintenance
- Practical experience of the realities of industrial life
- Checks to eliminate calculation errors in design
- Check to ensure that the product is made to drawing
- Adequate feedback in communication
- Environmental conditions on which the design was based should be same to actually applied.
- Component or structure should be manufactured to drawing
- Adequate design for the forces and environmental conditions in service
- The statutory provisions must not be violated
- The safety codes/standards strictly to be complied with

REFERENCES CITED

1. Richard Booth, "Structural Failure", Aston University, England (1988).
2. National Safety council, "Accident Prevention Manual", International Standard Book No. 0-87912-136-X (1988).
3. Accidents at project site -1996 to1998 (where author was working).
4. Trevor A. Kletz, "what went wrong", Gulf Publishing Company (1985).
5. Loss Prevention Bulletin, Vol. No.4, Oct.-Dec. (1985).