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Review of Risk Factors of Construction Site Fire and Suggestions for its Mitigation

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***Abstract* – India lacks guideline for fire safety at construction sites. But site contains all normal elements of an existing building that can pose fire hazard plus many extra risk factors such as flammable chemicals, spark-generating tools, inadequate provision of fire protection system etc. Hence, risk associated with fire at sites for new construction alteration or demolition is higher. Human response performance is also poorer for site fire adding to the seriousness of the problem. While in India, infrastructure is booming and at the same time many devastating fires have taken place in recent years, it is hightime to formulate guidelines to control site fire. Considering the limitation of using a conventional fire protection system at site, this paper reviews fire norms prevalent in other countries and highlights the major concerns. In this context, extended role of various key players of construction industry such as designers, contractors, clients etc is also discussed.**

***Keywords :* Construction site, Demolition, Fire hazard, Fire response, Site fire**

I. Introduction

Fire costs 2% GDP in developed counties and endangers numerous lives [1]. Each year, an estimated 4800 construction site fires cause loss of $35 million of properties in US. In UK there are around 11 fire incidents in construction sites every day [10]. In India, fire hazards were reported at Common Wealth Games construction site, where PVC sheets installed at a height of 45 feet caught fire [11] and construction material catching fire from sparks of wedling machine at Kolkata new airport terminal [#]. On the other hand, fire in existing buildings has caught attention recently. For example, within a short span of time, Kolkata has witnessed several notable fire accidents, namely [2-6], Nandaram Market of Burrabazar in 2008, Stephen Court of Park Street and Ultadanga slum in 2010, AMRI hospital of Dhakuria, a rubber factory in Tiljala in 2011, Surya Sen Market in 2013 etc.

After 91 lives were lost in fire incident of AMRI Hospital, government has put various public buildings and high-risers under scanner. Compliance with National Building Code 2005 or NBC 2005 [7] is being checked for all such existing buildings. NBC exclusively deals with fire protection system recommendation of existing building of various types and does not include fire safety of buildings under construction or construction sites. Similarly, codes by Bureau of Indian Standards also do not cover this topic. E.g. IS 2190: 2010 for fire extinguihers, or IS: 1641 – 1988 (Reaffirmed 2002) for FIRE SAFETY OF BUILDING. The only mention about fire protection at site in Indians context is noted for checking whether the construction of fire-resistant building elements and installation of fire protection system is as per recommendation or not [8].

"During construction stage of the building/ development work, Fire Protection consultant shall carry out occasional inspections as directed by the Chief Fire Officer, for ensuring that all fire safety measures are being observed by the contractors' employees and all others at site".

Unfortunately no inititives has been taken for mitigation of fire hazards in construction sites. From the given statistics, it is dangerous to assume that Indian construction sites are very safe against fire as reports note that the construction industry is the largest employer of unorganised labour force in India and these people are exposed to occupational hazards 4-5 times more than the manufacturing industry [TMS141]. In fact it essentially means that construction fires are overlooked and not reported. Hence it is apparent that fire safety of construction sites is a highly neglected

area in India. This is a major concern at this juncture of time, when the country is having many infrastructure and construction projects due to its economical growth [9]. This paper will explore the need of fire safety regulation at construction sites including new construction, alteration and demolition work. In order to make any recommendation to minimize risk factors of fire at construction sites, first we should identify the risk factors and check whether construction sites pose higher risk of fire by reviewing:

- Causes of fire and their presence at construction site;
- Provision of fire detection, notification and suppression at sites;
- Occupants' fire response performance;
- Heightened risk at demolition sites.

II. Causes of Fire and Their Presence at Construction Site

For demonstarting various causes of fire hazards, the traditional fire triangle of oxygen, fuel and heat is replaced by the concept of fire tetrahedron with the fourth element of chemical chain reaction [12].

- Oxygen: The main source of oxygen is supplied by natural air. Compared to enclosed structures, unfinished buildings or sites have more channels for airflow and is more likely to show 'chimney effect'. Stored oxygen used in welding processes or oxidising agents can worsen the situation.
- Fuel: Here any inflammable or combustible material should be considered. Apart from normal building materials present in both finished and unfinished structures, construction site has various other elements serving as fuel such as, un-cleared debris, stored cans of paints, varnishes or thinner, protective coverings, scaffold sheathing, fall-arrest bags, acetylene for gas cutters, temporary shelters etc. Many of these can give out toxic fumes resulting in reduced vision and poor way-finding performance [13]. More people die from smoke and toxic gases than burning [14].
- Heat sources: Common heat sources in construction sites are different from that of occupied buildings. For example, open-flame hand-held equipments, asphalt or tar boilers, burning debris, exhaust from heavy machineries, faulty or incomplete electrical wiring, heat generating process such as welding or friction cutting, halogen lamps burning throughout the night at very close vicinity of stacked combustible material etc.
- Chemical chain reaction: It also has higher probability to take place at sites as various types of material and chemicals used during constructions are more in variety and quantity compared to completed facilities.

A. Temporary Accommodation Units (TAU)

TAU requires a detailed mention. It can be a hut for smaller projects or even can be multi-storeyed structure if the project is big. Usually such shelters are made on site for site offices, canteen, first-aid facility or resting. Each of these uses demand different types of fire protection [15]. However, many times one facility often caters for other usage for which it is not built. For example, a site office with basic fire protection system is used to store highly flammable materials from time to time or partially finished buildings are used by workers for resting or cooking which violates the basic rule of locating TAU away from main structure. Such unplanned situations lead to high fire risk.

III. Provision of Fire Protection System at Site

Fire protection system comprises of passive and active components. Provision of escape routes, refuge area and compartmentalization are covered by architectural planning, while fire rating of the structure is covered by civil engineering. These two factors can be grouped under passive fire protection system which gives protection to the building all the time. On the contrary, active fire protection system comprising of detectors, alarms, hydrants, sprinklers, hose-reel and portable fire extinguisher is useful when a hazard occurs [11]. Chew and Das [16] have mentioned about 35 common defects in active fire protection system, out of which 16 were found to be critical in terms of frequency of occurrence or effect on system performance, health-safety-comfort or economic profile. Their findings cover six major components namely, detection & communication system; hydrant, fire hose, sprinkler system; portable fire extinguisher and services for fire escape. Though the result deals with occupied commercial buildings, it is highly applicable to any installed fire protection system.

But in this particular case, the major concern is whether a proper passive or active fire protection system is planned,

installed and maintained for a construction site. Is it updated on regular basis? It should be noted that unlike completed buildings, sites have a dynamic physical condition [15, 17]. Last week, where a trench was dug, this week the place may house a crane and next week the crane may move out and give space to stacked material. Hence, it is not uncommon that an initial escape route does not exist at all when fire occurs after construction has progressed significantly. Hence, guidelines for site fire protection are more generic and flexible which appears as special fire norms in various countries as shown in the following list [17-21]:

- NFPA Standard 241 of National Fire Protection Agency (NFPA), United States;
- National fire code of Canada 2010, Canada;
- Guideline no. 21 CFPA-E No. 21:2009: Fire prevention on construction sites, Europe;
- Joint code of practice– Fire prevention on construction sites (7th Ed.), UK;
- Notice No.13, Fire protection at construction site by Fire Service Department of Hong Kong SAR.

Unfortunately there is no such provision for Indian context. Looking at the violation of existing rules for completed buildings which has got clearance from local fire department, it is doubtful that how much imitative are taken by owner or contractor for fire protection at construction sites. Especially when there no such statutory requirement and the cost incurred for such safety measure is high and intangible.

IV. Occupants' Fire Response Performance

The three distinct strategies for surviving a fire are: (1) extinguish it; (2) evacuate or (3) take refuge and wait for rescue [22]. Extinguishment is possible, if fire is detected and notified at early stage, people have knowledge to analyze type of fire and they can use the suitable fire fighting equipment or notify the fire brigade on time. Unfortunately, construction sites often lack such fire fighting provisions. If noisy work is going on or site is almost vacant at night, manual notification is unreliable. Similarly, refuge place built with recommended fire-rating is a rare provision at common sites. Rescue operations by fire-fighters and emergency treatment by paramedics are typically available after fire has crossed its first stage − the most suitable stage for evacuation. Hence, success of evacuation largely depends on occupants' fire response performance.

Such performance in turn relies on: occupants' mobility, mental alertness, preconception or awareness about fire hazard, familiarity of the space for way-finding [23]. That means same person may behave differently in different locations which corresponds to his/ her adeptness to the situations based on available information and opportunities. People at risk at site are workers, supervisors, people at near-by premises, contractors and client. For refurbishment project, the building is partially occupied by normal users. People who may be especially at risk are [15]:

- People working alone or at isolated area, e.g. security guard, staff on cranes;
- People unfamiliar with the site, e.g. new crew, sub-contractors or visitors;
- People with special need such as speech, hearing or language difficulties.

Kobes et al. [24] describe human factor as people's behaviour in a fire. It relies on individual, social and situational aspects as explained in the following section.

- Individual aspect: People's decision depends on their knowledge, experience, observation power, judgment, and mobility. Usually in unfamiliar situations, people panic, try to follow others blindly and choose an escape route which is appears to be shorter and safer;
- Social aspect: Bonding among people present in fire helps spontaneous group formation and eases rescue operation. For example, a family shows deeper commitment to inform members as fast as possible and try to rescue them as long as possible;
- Situational aspect: Alertness, physical position and familiarity with the building layout constitute situational aspect. Site-works are often dangerous and noisy compared to normal indoor activities. It may affect alertness of workers and delay in conveying the information about a fire. Mobility can be reduced for those involved in particular tasks such as working in trench or at height with safety gear such as cleaning gondola or material lift. They need other's help to reach a level suitable for escape.

Nowadays, it is a common trend that more and more subcontractors are involved in a project rather than one main contractor with different crew. People under a particular subcontractor work for a definite period and focus only on their core business. Neither they try to appreciate and understand the entire project nor they are bothered about others or their works [25]. Also many contractors hire unskilled labourers on a short term basis who don't get proper training on how to react in case of fire and also unfamiliar with the entire site. It is mentioned earlier that unlike completed buildings, sites have a dynamic physical condition. It may result in unfamiliarity with the situation and lack of long-term social bonding with a co-worker which leads to slower human response. Usually instead of a conventional fire drill, general and flexible guidelines are given about nature of fire, types of extinguishers and whom to contact in case of emergency [17].

V. Heightened Risk at Demolition Projects

Fire risk for demolition projects is considered higher than new construction as the magnitude and complexity of the fire accident increases not only with project size but also corresponds to age profile of the existing building [26]. Usually very old or damaged buildings undergo demolition. Often it is difficult to assess fire rating and structural integrity of such buildings. Especially after progress of demolition work to certain extent, various parts of same building exhibit varying levels of system integrity, exposures and vulnerabilities. Hence in case of fire, there is a higher probability of people getting injured by falling debris [10] or fire spreading through hacked or blasted portions [17]. Deconstruction process involving controlled blasting with explosives, steel cutting and burning of debris are common causes for fire. Here amount and variety of debris are usually more than a new construction Moreover, for bringing down large towers in congested urban areas scaffolding or vertical barriers are needed which limit access for rescue or fire fighting operation [27].

For preventing such increased criticality, unfortunately fire protection system is inadequate or even non-functional for most of the cases. Typically the fire detectors, fire doors, sprinklers etc are removed before the main structure is brought down. Hence various inflammable materials remain present at site without any fire protection. These unwanted materials if not regularly cleaned from the site, can also block the evacuation route or access for fire engines.

These arguments can be illustrated through the following examples. In the first case, the supplier informed ceased supply of piped cooking gas in properties under renovation. His informal words were not vrified and fire broke out at the site [#]. In the second case, inferno took place in Deutsche Bank of New York [27]. The Building next to World Trade Centre was so heavily damaged and contaminated by 9/11 incident, that it was undergoing floor-by-floor demolition in 2007. On August 18, the 40 storey tower was already reduced to 26 storeys while a massive fire broke out on 17th floor engulfing 10 adjacent floors, killing two firemen and injuring 115 others. Though the root cause is assumed to be careless smoking by workers, but other factors contributing to the tragedy were:

- Smoke was trapped by maze of polythene sheets used for debris removal.
- Non-operational riser and sprinkler.
- Highly flammable plywood was used to cover facade openings to prevent asbestos or other garbage from spreading into surrounding.
- Asbestos stripped from beams left gaps and holes in the structure that gave easy pathway for the flame and smoke.

Firemen at 14th floor assumed that they were safely below the blaze and in a prime position to tackle it. Suddenly they were surrounded by fire and thick black smoke leading to death. Here contrary to normal trend, fire and smoke travelled downwards through the hacked gaps. Hence conventional tactical operations cannot be implemented in case of demolition and can be proved fatal for the fire fighters [27].

VI. Suggested Remedies

Guidelines for site fire protection for various countries can be consulted to develop such code suitable for Indian scenario. Here, their common requirements are discussed to illustrate the major issues of concern [17-21]. Once this focus of safety plan is precisely set, development of remedies in order to mitigate site fire risk can begin with systematic approach of risk management and distribute its responsibility among key players of a project.

A. Common Guidelines of Site Fire Protection

- Fast installation of proper fire protection system.
- Orderly and minimum storage of combustible materials.
- Extra precaution or preferably avoidance of dangerous goods and processes.
- Regular removal of discarded materials to ensure an unobstructed exit route.
- Adequate number of staircases to cater all floors.
- Strict 'No Smoking' especially where highly inflammable material or high-risk works are present.
- Electric load must be within limit and have proper wiring, insulation, earthing and circuit breakers.

B. Management of Site Fire Risk

Alike any other risk management the four basic steps are [15, 28]:

- Identification: Source of heat, fuel, oxygen, chemical chain reaction and people who are at risk.
- Estimation: It is checked the chance of occurrence of fire, its nature and probable effect on people and property.
- Response: As per findings from two previous steps, emergency plans are developed, people at all levels are informed and instructed so that they can co-operate and coordinate in case of emergency.
- Review: Previous steps are monitored to find their efficiency. Frequent review and update are needed to cope up with dynamics of site condition and workforce is transient.

C. Role of Key Players

Such risk assessment can be successful if and only if the major players in the project understand and appreciate the need for site fire protection in order to adopt extended responsibility.

1. Role of Client

Client sets the vision of a project, selects competent team members and bears extra cost for health and safety. Client is supposed to provide site related information to designers and contractors such as:

- Existing usage of the building, buried services, fire safety rules;
- Previous use of site, building or storage unit;
- Available facility for site storage and rubbish disposal;
- Type and proximity of neighbouring buildings.

2. Role of Designers

Design process includes drawing, detailing, specifications and bills of quantity. Apart from the concerned people, contractor and client who also contribute in giving the final shape to the design are recommended to:

- Release complete details of fire protection system as soon as possible;
- Consider potential risk to surrounding premises and electrical load of construction equipments;
- Minimize amount and variety of inflammable materials and building elements that need high risk construction/ installation process;
- Plan construction sequence to allow temporary refuge place if needed;
- Take special precaution for high-rise projects and alteration/ refurbishment projects which accommodate both normal use and construction.

3. Role of Contractors

They need to plan, manage and co-ordinate health and safety during construction. Main contractor helping in fire risk assessment must liaison closely with sub-contractors – particularly for high fire risks in order to implement the fire safety plan. In general contractors are responsible for:

- Stating fire norms in the contract and adhere to the same;
- Procure and store flammable substances;
- Rubbish storage, clearance and burning;
- Safety training and safety notices;
- Strict control over high-risk processes, tight vigilance and regular inspection;
- Applying similar rules for temporary units;
- Bringing all workers under the safety norm.

VII. Conclusion

Higher risk potential of causes of fire hazard and inadequacy of a proper fire protection system make construction sites dangerous. As a result, fire safety at construction site is difficult to achieve. Fire load as well as fire risk change with progress of construction and it requires modification of designed solutions to current conditions. However Indian codes are yet to incorporate these mandates. Enormous attention has to be paid for forming rules for new construction and as well as for alteration and demolition work. Concern for site fire safety must be embedded in the project goal itself and implemented throughout the project lifecycle. It demands systematic risk management and active participation of major stakeholders of a project to achieve the same.

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