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# Analysis of the case of fire fighters casualties in the building collapse

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## Abstract

Using the "2-4" model of behavior safety to study the cause of the fire fighters sacrifice caused by the building collapse since 2003, the direct cause of deaths lies in unsafe act and the unsafe state of the material. To analyze further, the lack of safety knowledge and weak safety awareness, the lack of safety habits is the remote cause of the casualties, the fire brigade's security management system is the primary cause of some problems, the construction of fire safety culture is the root cause. The focus on fire prevention and investigation, and improvement of the system of full-time security staff, the establishment of a unified system of fire accident investigation, the implementation of the disposal of the program to prevent such incidents from happening again were put forward in this article.

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*Keywords:* fire fighter; "2-4" model; unsafe act; fire safety culture.

## 1. Preface

According to the data statistics, hazards endangering the fire fighters life safety can be divided into seven categories, namely: the collapse of the building, explosion (deflagration) or flashover, fall or drop, electric shock, gas poisoning, traffic accident and other accidents. Building collapse, explosion ( deflagration ) or flashover caused the most serious firefighters sacrifice, accounting for 73%, and firefighters sacrifice due to building collapse accounted for more than 36% of the total number of sacrifice [1]. Building collapse in the fire has the characteristics of a suddenness, strong destructive, large casualties and personnel evacuation difficulty. It is experienced that the general material volume exceeds the building capacity of 1/3, building fire resistance rating of two, long burning time is easy to collapse.

How to avoid and reduce the fire fighters sacrifice has been the focus of the fire fighting forces. Through the analysis of the fire fighters sacrifice cases which had been caused by the building collapse since 2003, the direct cause of the accident is concluded using the "2-4" model, and the indirect cause, primary cause (the management system) and root cause (fire safety culture) are also put forward. Thus in order to prevent similar tragedies the effective and reasonable accident prevention route was presented on these grounds.

## 2. Interpretation of the accident cause by using the "2-4" behavioral safety model

### 2.1. Case analysis

Through the review of *China Fire Yearbook* [2-7] in recent years and news report about fire fighters casualties caused

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by the building collapse since 2003, the accidents were counted. The direct cause of 17 accidents was found including persons unsafe act and unsafe state of material. Unsafe act mainly refers to fatigue operation, not alert to the scene changes, blind operation, (risk operation), personal protective equipment is not dressed as required, inadequate or lack of protective measures, no safe place to take emergency measures, in unsafe position. Unsafe state of material mainly refers to building fire over time, the large fire load, unclear fire scene.

From the collapsed buildings, there are several circumstances, a: the burning time of construction surpass the fire resistance or building load surpass its load capacity causes the whole building collapse and causes fire fighters casualties, such as case2、3、4、16、17; b: roof truss structure by the flame high temperature lose ability to support and collapsed --roof or ceiling collapsed, give rise to fire fighters death, as the example of case 8、14、15; c: the wall is caused by a high thermal expansion or an external force to cause a collapse accident, give rise to fire fighters death, for example case1、5、9、10; d: due to the inherent cause of building structure design or construction materials in high temperature bearing lose, induced by beam or girder collapse, give rise to fire fighters death, for example case 6、7、11、12、13. Forty seven firefighters were killed and sixty one man were injured in 17 accidents--huge casualties.

The National Standard Technology Agency (NIST) and the Phoenix Fire Department said that the general lightweight framework of residential buildings from the fire to the roof collapse is less than 20min, without any warning. Although the fire fighter training tells them that their own safety is very necessary, they are unable to predict the safety operation time, often cannot choose to evacuate. Time provided by Specifications is only mechanical data, it is difficult to effectively reflect the actual fire safety time, the collapse is often not any omen occurs quickly, and firefighters completely unaware that they are in danger [8].

Table 1. The fire fighters casualty cases caused by building collapse

Number	Time	Casualty figure	Accident process	Unsafe act
1	2015-2-24	1dead	Farmer house fire at Xiaofeng Village Muyun Country Fu'an City, the houses wall was collapsed, suddenly a fireman died	Not alert to the scene changes (protective measures are not in place)
2	2015-1-2	5dead 14injured	Warehouse fire at North Nanxun ceramics market, 11 story building collapsed, 5 firefighters were killed	Not alert to the scene changes (the building has been in fire over 2 hours)
3	2014-2-4	2 Dead 2injured	A plant fire at Minke Road Baoshan District , the fire plant suddenly collapsed when the fire was soon to be extinguished, resulting in two soldiers buried	Not alert to the scene changes (in an unsafe place, the factory has been in fire over 2 hours)
4	2013-10-12	2dead	Xilongduo shopping mall fire at Pingguoyuan South Road Shijingshan District, due to the rapid spread of the fire building suddenly collapsed, two fireman died	Fatigue operation (failed to find the signs in time )
5	2013-2-25	1dead 1injured	Houses fire at Chenbu village Wuyang Town Ruijin City , in the course of fighting, soldiers were buried by the collapsed walls	Personal protective equipment is not worn as required (the helmet is hit by a brick)
6	2012-10-7	1dead	Six stores burst fire at Heshan Road Xingbin District Laibin City, in the rescue operations soldier was hit by collapsed beam above the pull gate	Not alert to the scene changes (protective measures are not in place)
7	2012-2-1	1dead 1injured	Ting Xin Jie Dayun Precision Co. Ltd. fire at Suzhou Industrial Park, in further search and rescue process, the soldiers were hit by storage rack and unfortunately inhaled excessive smoke and choked	Personal protective equipment is not worn as required (the safety rope was buried pressure, the SCBA alarm,but firemen did not withdraw)
8	2011-2-6	1dead 2injured	A two-story brick structure houses fire at Langtian Village Zuolong Town Ji'an City, in the process of fire, fire building suddenly collapsed, three soldiers were buried	Not alert to the scene changes (Housing fire overtime)
9	2010-4-7	1dead 2injured	Xincheng Plastic Co. Ltd fire at Yanggu City Shandong Province, in the process of fire, the wall suddenly collapsed, firefighters in the combat were unfortunately hit	Not alert to the scene changes (factory fire overtime)
10	2008-07-21	1dead	A furniture factory fire at Longjiang Town Shibuyang Development Zone, the wall on the west side of the factory suddenly collapsed when they cleaned up the scene of the fire , the fireman was suppressed	Not alert to the scene changes ((protective measures are not in place,no time to escape)
11	2008-7-17	3dead 9injured	IKEA plastic factory warehouse fire in the suburbs of Shanghai Fengxian District, a serious hidden danger of the building structure of the 50 meter main beam suddenly collapsed, resulting in a number of firefighters pressed	Personal protective equipment is not worn as required (Smoked down )
12	2007-10-8	2dead 5injured	The scaffold hanging collapsed in the construction of elevated plant on the south side at Wifu Thermal Technology	Blind operation (regardless of danger, rushed into the collapse site,

			Co. Ltd Zhangjiagang City, 5 workers shed hit, 10 workers trapped workshop, in the rescue process cement beam of south side wall suddenly collapsed, seven fireman pressured in the rubble	the sight is not clear, a furious storm)
13	2007-4-22	1dead 1injured	Huanqiu fishing tackle shop burst fire at Weihai City, the girders of the second workshop suddenly collapsed after 2 hours, two fireman were buried	Not alert to the scene changes (factory fire overtime)
14	2006-5-8	1dead 8injured	Xinjiang construction machinery factory warehouse fire nearly 3000 square meters at Qiantangjiang Road Urumqi City, warehouse roof suddenly collapsed in search and rescue process, a firemen quickly pushed aside his comrades, but he was buried under the floor	Blind operation (no avoid danger in time, large fire load)
15	2005-8-2	3dead	Mengniu Dairy Group ice cream factory cold storage fire at Maanshan City, 22 meters high and 80 meters long and spans about 40 meters of the steel frame structure collapsed down, heavy pound the three fire fighters	Blind operation (did not ask for instructions)
16	2004-7-26	1dead 4injured	Xianglu mosquito repellent incense factory fire at Pingxiang Town Yongan city Fujian Province, because the whole plant collapsed suddenly, warehouse in a large number of burning powder, wood powder as raw material, and the heating air together jet out from the pressure relief doors and windows and holes, firefighters can not leave the scene in time, were instantly burned by a large number of high-temperature heavy fuel	Equipped with protective articles of the level is not enough
17	2003-11-3	20dead 1injured	Hengzhou building fire at Hengyang City, the building suddenly collapsed during the fire fighting and many fireman were buried	Not alert to the scene changes (housing fire too long, did not pay attention to the collapse of the precursor)
	total	47dead 61injured		

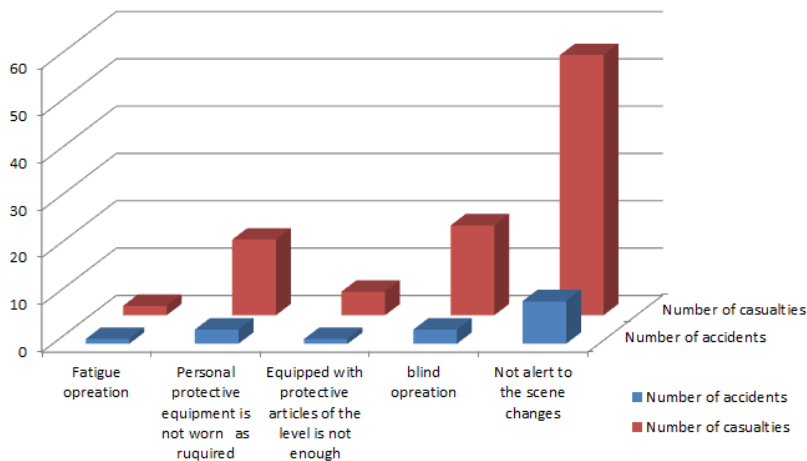


Fig. 1. Relationship between unsafe act and the number of accidents

2.2. Author Artwork

From table 2, the causes of the accident are divided into two levels of organizational behavior and individual behavior. Organizational level of safety culture (source), safety management system (root cause) and personal level of habitual behavior (indirect causes), one-time (direct cause) link to 4 stages. These 4 stages constitute a behavior chain. Any accident occurs within an organization, and is directly caused by the members of the organization, but it is fundamentally determined by the organization's safety culture and safety management system [9].

2.2.1. Direct cause

From table 2, we can see that one of the immediate causes of the accident is the “unsafe state of the material”. It may be the result of individual act, or it may be the result of personal habitual behavior, but also may be the human act before the existence of material and environmental factors; Another direct cause of the accident is the "unsafe act". From 17 buildings

Table2: The "2-4" behavioral safety model

Chain name	Development level and stage				Development result	
	The first level (organizational behavior)		The second level (individual behavior)			
	The first stage	The second stage	The third stage	The fourth stage		
Behavior development	Guiding behavior	Running behavior	Habitual behavior	One-time behavior	Accident	Loss
Reason classification	Root cause	Primary cause	Indirect cause	Direct cause	Accident	Loss
Accident cause chain	Safety culture	Safety management system ( system file and running process )	Insufficient safety knowledge Weak safety awareness Lacking safety habits	Unsafe act Unsafe state	Accident	Loss

collapse accidents it can be seen that it is mainly related to the fire commanders and fire fighters. People's unsafe acts mainly refers to fatigue operation, blind operation, personal protective equipment, inadequate or lack of protective measures, no emergency measures, in an unsafe location. Unsafe state mainly have building fire overtime, the large fire load, unclear fire scene. Among seventeen building collapse accidents, the vast majority of cases are related to the damage to the building function after the fire, bearing capacity decline, that is, itself exist unsafe conditions. However, due to the limitations of the firefighters' own experience, they did not notice the collapse omen. Or in most of the time there is no sign of the collapse of the building, but also caused the casualties.

2.2.2. Indirect cause

From the above cases, inadequate or lack of protective measures, no emergency measures, are the main acts that cause the fire fighters casualties, reflecting the weak safety awareness of the fire fighters' self protection. For a long time, from the soldiers enlisting, college training and combat operations, fire brigade focuses mostly on the heroism, sacrifice, patriotism in fire rescue operations without paying attention to the great importance to the fire fighters self protection in theirs work [10]. Fatigue operation, risk operation, in an unsafe location reflect the fire fighters safety habit is not good. In the process of fire fighting, the omen of the building collapse was not noticed by fire fighters, which cannot immediately evacuated, or firefighters could not predict the safety operation time, often cannot choose to evacuate. There are often no signs of a rapid collapse, and firefighters are completely unaware of their own risk, reflecting the lack of safety knowledge and experience in this area.

Unsafe state mainly refers to building fire overtime, the large fire load, unclear fire scene. Although there is a material environment factor that exists in human action, the firemen should recognize these risks and take necessary precautions. Combined with case analysis, many buildings have been burned long time, but personnel is still inwards to attack the fire, reflecting the lack of security knowledge of the command staff.

2.2.3. Primary cause

According to the fire forces status quo, all levels of military officers are responsible for the health and safety of firefighters, headquarters responsible for implementation.

Among 17 accidents, firefighters casualties caused by fatigue operation, risk operation and personal protection problem and so on shows that the operation system of fire safety management has some problems. If the commander has a full professional knowledge practice and the strong safety awareness, the fire fighters are not allowed to work with tiredness and risky state, then it will effectively avoid casualties.

In order to strengthen and standardize the troops safety work in the training and fighting, the Fire Bureau specially formulated and issued *police fire brigade combat and training safety guidelines*, but there is still a deviation in the implementation at some basic units. In view of the weak protection awareness of the fire fighters, supervision is not in place. Due to lack of experience, valor, recklessly phenomenon, caused casualties of combatants. Hot smoke, burning, fire wall, simulation chemical companies, etc. training facilities are not ample enough at part of the Corps and detachment. Adaptability and disposal of the technical and tactical training is not thorough and extensive at the circumstances of simulation actual combat environment at high temperature, smoke and oxygen deficit, high altitude lifting, collapse, fireman's emergency hedge skills are not very strong [11]. Once in a critical situation in the field, often can easily caused casualties. The solution is to strengthen the management system construction, improve the running behavior control.

#### 2.2.4. Root cause

From the above-mentioned 17 accidents, many accidents occurred because of fireman's lacking safety awareness and habits of the firefighters, resulting in unsafe acts, thereby causing casualties. The root cause is that the management system is not perfect. Fire forces may focus on the rush to rescue people, but for their own safety, in practice, the emphasis is not enough which is reflected in the insufficient construction of the security culture. But its source lies in fire forces for the conflict between the life safety and disaster relief deals not good, and establish a "people-oriented" concept of security at all levels of the fire rescue work is not yet in place [12]. These are precisely achieved through safety training, safety training, safety risk assessment, and other security culture. If the safety culture of the characteristics of fire force is constructed well, it can effectively reduce the occurrence of the accident, and then eliminate the occurrence of the accident.

Whether if the manager is aware of the security is the most important factor affecting the stability of the army. Security goes first. Security is equivalent to the effectiveness, determining the improving level and implementation status of the organization's security management system. Awareness of safety culture elements (List of safety culture elements [13]) is response to the level of safety culture construction, that is the control loss of the organization's behavior culture guide. Such as elements 20: the type of accident investigation, the fire accident case investigation and analysis ignore the analysis of errors and failures, too rendering the spirit of regardless of personal danger, less carefully investigate from the disaster scene enhanced personal safety points. With special case summary, false phenomenon is serious. Such as elements 9: the formation of the safe values, by the military service system, the average service age of each fireman is 2-3 years, the time of formation of complete safe values is too short. Elements 25: facilities satisfaction, due to the great difference between the fire investment all over the country, resulting in different fire facilities configuration. Facilities in the underdeveloped areas are very slow, backward, and even the most basic personal protective equipment is not enough. Element 18: the formation of the security system; element 19: the implementation of the security system. The personnel security system established by our country has the problems such as responsibility is not clear, the quality is not strong and the role is not obvious. If the safety and cultural elements are well known in 17 accidents, the management system will be perfect, the accident will not happen.

### 3. Strategies to prevent the deaths of firefighters

According to the "2-4" model, the causes of the casualties caused by the building collapse accident were analyzed, and then accident prevention measures are formulated according to the causes to reduce the occurrence of fire accidents and improve the health and safety of firefighters.

#### 3.1. Focus on investigation before the fire

Before fighting against the building fire, the buildings within the jurisdiction should be investigated one by one, including the building of the refuge floor, evacuation, fire facilities and other condition. In order to successfully fight against building fire, the key lies in the protected objects are investigated in advance, fire drills are carried out, a special operation process are set up. If the internal situation are well mastered, fighting operation according to the original plan, fighting operations can be able to succeed [14].

#### 3.2. Perfect the system of full-time security officer of the fire brigade

When a fire fighter is carried out for fire suppression, it is usually in marshaling operations, and each working group shall designate a full-time security officer. To improve the safety of the fire organization at all levels, the personnel security responsibilities are set up at the whole process of fire fighting and rescue.

### 3.3. Establish a unified system of fire accident investigation

The national fire department should establish a unified data acquisition system, the case and investigation report of the fireman's should be preserved permanently for access and research. The accidents of the firefighters are informed regularly, timely reporting to the army to organize and conduct fire fighting case studies, to take measures to improve the safety conscience of the fire fighters from the idea to prevent similar incidents from happening again [15].

### 3.4. Awareness of the implementation of the disposal process

In the fire fighting and rescue, the ten basic disposal procedures should be strictly followed: dispatched alarm, personal protection, on-site consultation, detection, the establishment of the warning, evacuation rescue, eliminate the danger, on-site first aid, decontamination, wash away and transfer. The safety conscience is set up in each link and the fireman must not cut the program, reduce the requirements. *Fire fighting and rescue operation guidelines* should be classified and constituted as soon as possible to improve the normalization and safety of the rescue.

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