THE COUNTERMEASURES TO THE POLLUTIONS OF SMOKE OF HIGH TEMPERATURE IN PASSAGEWAY OF UNDERGROUND BUILDINGS*

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ABSTRACT

Due to underground spaces are opened up and used in our country, the underground shops, hotels and recreational halls emerged in large numbers; Besides, the fire in the underground buildings had happened sometimes, In the view of above fire instance, the fire-pressure occured in the fire of the underground building and its expression are advanced in the articla. In the meantime, on the basis of thermal exchange between the high temperature smoke in the underground passageway and the walls of the underground passageway, the equation of conservation of energy in the thermal form is built and the expression of change of temperature difference of the smoke which moves along the distance of the underground passageway are therefore given in the article, in the meantime, a calculated table corresponded to above equation is given. According to the theoretical formula of the fire pressure and corresponded calculated table of high temperature smoke moving in the underground passageway, the thermic and smoke pollutions caused by the high temperature smoke in the passageway of the underground buildings are raised. Lastly, some corresponded countermeasures polluted by high temperature smoke to the passageway of the underground building are put forward in the paper.

INTRODUCTION

In the use of underground spaces, especially, in the underground shops, because of the interactions between the safetyless action of the men and the safetyless states of the materials, when the burning conditions formed in the interactions, thus the fire in the underground building that brings great suffering to the country and people is caused sometimes. For example, at 1 O'clock in the

* The project is supported by Natural Science Foundation of China.

morning of septamber in 1988, a great fire in a underground shop had been caused by electric spark and lasted about 11 hours. It burned and damaged 3/5 of the whole passageway in the underground shop, fortunately nobody was suffered.
It is common knowledge that both underground building and high building seem to be 'a great stovepipe', the difference between both lies only in different positions of 'tow stovepipes', that is to say, the 'stovepipe' as the high building was built vertically, but 'the stovepipe' as the underground building was constructed horizontally and burried under earth.
Consquently, in other words, the underground building is like 'a great underground chimney' placed under earth, and the people and materials in the underground passageway are like 'expensive fuels' too, if the fire is happened then 'the expensive fuels' will be commited to the flames.
The characters of the fire in underground building summarize as following:
(1) due to electric equipments and wires in underground building are often in a hygrometic environment, they will become hidden danger of the fire in the underground building. In the meantime, the underground passageway will be in dark when the fire is happened.
(2) due to a host of people gathered in the underground passageway, when the fire is happened, it is very difficult to evacuate people in the underground passageway safely.
(3) due to a host of burnable materials gathered in the underground passageway when the fire is happened, a large number of the smoke decomposed in a high temperature by burning materials will diffuse in the underground passageway and polluted whole passgeway.
To sum up, the characters dicided by the fire behaviour in underground passageway had leaded to great difficulties of the evacuating persons and putting out a fire.

FIRE-PRESSURE IN THE FIRE OF UNDERGROUND BUILDINGS

It is known that difference of temperature between inside and outside of room gives rise to difference of pressure between inside and outside of room, that is known 'thermal pressure', equally, difference of temperature caused before and after fire will set off a difference of pressure between inside and outside of room, that is called 'fire-pressure'.[1]
Supposing the height of the passageway in underground building is h, and the air temperature in the passageway is t_1, and smoke temperature is t_s. thus the fire -pressure occured before and after the fire is Δh_f:

$$\Delta h_f = -(t_s - t_1) r_1 \Delta h / t_s = -\Delta t_s t_1 \Delta h / T_s \qquad (1)$$

here Δt_s-the temperature difference between smoke and air in the underground passageway. [℃]

r_1-the unit weight of the air in the passageway. [kg/m³]

T_s-absolute temperature of the smoke. [k]

The sign '-' expresses the smoking to flow up.

Must point out that the fire- pressure expressed by expression (1) is fountainhead causing the diffusing smoke in the underground passageway, and achcriminal to bring pollution to the underground passageway also.

Practically, the size of the underground passageway is generally as follwing:

$\Delta h=4.0$ [m], $r_1=1.185$ [kg/m³] ($t_1=25$ [℃]),

on the basis of the expression (1) the value of the fire-pressure is $\Delta h_f=-33$ [pa]. The value provided scientific basis for pressurized ventilating and exhausting the smoke in the underground passageway.

THE MOVEMENT OF THE SMOKE ALONG THE UNDERGROUND PASSAGEWAY

The smoke of high temperature caused in the fire of underground passageway not only leads to the fire in underground passageway to spread further as second fire fountainhead, but also brings about heavy heat and smoking (toxic) pollution to the underground passageway as heat and smoke fountainhead, therefore the heat and smoke incur a greast danger to people and materilas in the underground passageway.

In the meantime, in the smoke moving along the underground passageway the smoke emits a lot of the heat, besides, the walls underground passageway absorb the heat. On the basis of the law of conservation of energy, expression of the change of temperature caused by the smoke moving along the underground passageway is obtained in the following states:

Supposing the dimension of cross section of the underground passageway is small as compared with its length, thus the smoke following along the passageway must be considered one dimensional flow.

Further supposing the smoke moving along distancer x in the underground passageway from starting point of the fire and the change of temperature of the smoke to be sut off by the fire is Δt_x, and the circumference of the cross section of the passageway is p, then when the smoke has moven and infinitesimal distance dx along the underground passageway from the point x, thus the quantity of heat absorbed by the walls of passageway on all sides of the length dx from high temperature smoke is dQ:

$dQ=k\Delta t_x pdx/3600$ [kcal/sec] (2)

here k – the exchanging heat conffiicient in convection between the smoke of high temperature and the walls of the passageway.

In the passageway the exchanging heat coefficient k is genrally given by following experimental fomula:

$k=2+k'\sqrt{u}$ [kcal/℃.m².h]

here, k – the experimental constant, generally, k' =5~10.

u – the following velocity of the high temperature smoke.

In addition, the quantity of head given out by the smok in the second is dQ':

$dQ'=-GC_p d(\Delta t_x)$ [kcal/sec] (3)

here G – the rate of flow in the quantity of the high temperature smok entering into the passageway. [kg/sec]

C_p – the specific heat of the high temperature smoke.

On the basis of the law of conservation of energy the following equation is obtained: [2]

$dQ=-dQ'$

$(kp\Delta t_x/3600)dx=-GC_p d(\Delta t_x)$ or $(kp/3600)dx=-d(\Delta t_x)/\Delta t_x$

considering $kp/3600C_p=C$, then $(C/G)dx=-d(\Delta t_x)/\Delta t_x$, lastly,

$\Delta t_x=\Delta t_m e^{-(C/G)x}$... (4)

here Δt_m-the change of temperature of high temperature smoke at the fire point occured before and after the fire.

The expression (4) expreses when the smoke goes through the distance x along the underground passageway, the change of temperature is caused at the point x in the underground passageway.

The value of temperature change of the smoke moving along distance in underground passageway in different conditions is given in the table (1).

THE CONTERMEASURES PREVENTING THE SMOKE

On the basis of expressions (1) and (2), the following suggestions to prevent smoke polluting to the underground passageway are given:

(1) in order to reduce the fire-pressure in the underground passageway the architect must cut down as low as possible on the height Δh of the underground passageway.

(2) the architect must increase as long as possible on the circumference p of the cross section of the underground passageway, under this circumstance the rectanglar section is most suitable, because it can induce greatistly the changing quantity of temperature Δt_x at the point x in the passageway.

In order words, the action of lowering temperature bewteen the smoke and the walls in the underground passageway is increased greatistly.

(3) The designer has to be meticulous in planning ventilation, that is the removel of the high temperature smoke and toxic gases and heat in the underground passageway to provide tolerable conditions for the people, especially, in the fire of underground building the smoke has reduced visibility of the people preventing effective rescue and fire-fight operations.

In addtion, the high temperature smoke can cause serious damage to the building structure in the underground passageway, therefore the designer must make the emergence measures pressurized ventelation to removel the smoke in the underground passageway, in general, the value pressurized ventelation is

$P > \Delta h_r = -33\,[pa]$

(4) Generally speaking, if the size of underground buildings is vast, the total distance of underground passageway is very long, therefore the designer must stall a water screen at every 25 meters in the underground passageway as emerged possable "separating wall", it is both to obstruct smoke extending and to evacuate safely peaple from the underground passageway.

(5) with the exception of above countermeasure, the designer must stall some safe refuge in the underground passageway, which is used pressurized smokeproof enclosure to ensure the people escapping from the fire point and get into the emerged safe refuge in the underground passageway.

The least distance required by smoke moving along passageway in different conditiongs Table (1)

velocity of smoke (m/s)		0.3											
vidth of passageway (m)		1.30						1.40					
height of passageway (m)		2.60			2.80			2.60			2.80		
temperature of fire point (°C)		400	600	800	400	600	800	400	600	800	400	600	800
rate of smoke temperature deereacing (△tx/△ts) (%)	0.1	23.25	17.92	14.60	23.82	18.33	14.92	26.45	20.35	16.57	26.12	19.75	16.90
	0.05	30.24	23.31	18.99	30.99	23.85	19.41	34.40	26.21	21.55	33.37	25.69	20.93
	0.01	46.49	35.83	29.10	48.50	36.66	29.84	52.88	40.70	33.13	51.29	36.60	32.17
	0.001	67.74	53.74	43.78	71.45	54.99	44.76	79.32	61.05	49.70	76.94	59.23	48.26

velocity of smoke (m/s)		0.5											
width of passageway (m)		1.30						1.40					
height of passageway (m)		2.60			2.80			2.60			2.80		
temperature of fire point (℃)		400	600	800	400	600	800	400	600	800	400	600	800
rate of smoke	0.1	32.58	75.07	70.42	33.36	25.65	20.90	34.74	26.33	21.45	35.91	27.63	22.51
temperature	0.05	42.38	32.64	26.57	43.40	33.36	27.19	44.53	34.25	27.91	46.70	35.95	29.23
deereacing	0.01	65.15	50.16	40.84	66.70	51.28	41.79	68.47	52.64	42.92	71.70	52.56	45.00
($\triangle tx/\triangle ts$) (%)	0.001	97.73	75.25	61.26	100.06	76.93	62.70	102.71	78.96	64.35	107.70	82.87	67.51

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