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DYNAMIC METHOD OF ASSESSING SEISMIC CASUALTY

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ABSTRACT: The concept of Initial Casualty Matrix is introduced. Using some probability distributed functions, the initial casualty matrix of masonry is determined. The Dynamic Method of seismic casualty assessment is established and then applied with the Tangshan Earthquake data, with some conclusions concluded.
KEY WORDS: Trap surroundings; Initial casualty matrix; State function of seismic casualty; Dynamic method

INTRODUCTION

Destructive earthquakes generally lead to great loss of life. The amount of seismic casualties caused by the Tangshan Earthquake (July 1976), Turkey Earthquake (August 1999) and Taiwan Earthquake (September 1999) is surprisingly large. On-site investigation and many studies suggest that seismic casualty were mainly attributed to building collapse, which kills the trapped if they are not rescued in time. Collateral disaster such as fire, landslide, flood and debris flow contribute to seismic casualties as well. At present, life loss relief is still of top importance for earthquake disaster reduction. The main task of emergency rescue during the early period after quakes is to rescue those trapped in ruined buildings, by making good use of all possible conditions. It appears very necessary to assess seismic casualties, especially the trapped, so as to give a quantitative reference for rescue action to be taken. Previous assessment methods in this field have several shortcomings as follows: (a) After-effect: the development of casualties during rescue period has not been taken into account. (b) The methods are mostly deterministic ones with not enough precision. (c) Only some, not all, of the factors that influence seismic casualties are considered. (d) Casualties induced by non-structural damage are ignored. (e) The humanist factors, in particular the psychological and physical factors of humans themselves, are seldom involved. To atone for these shortcomings, in addition to the Index of Seismic Casualty and State Function of Seismic Casualty defined by the authors elsewhere (Zhao Zhengdong and Zheng Xiangyuan, 2001), in this paper the concept of Initial Casualty Matrix is introduced firstly; then the Dynamic Assessment Method is presented to provide a new way to assess seismic casualties under the influence of various factors, with the Tangshan Earthquake as an example.

STATE FUNCTION OF SEISMIC CASUALTY

The mechanism of seismic casualties is quite different from that of structural damage caused by earthquakes. For constructions, their damage levels become stable soon after they have suffered quake. In contrast, the level of seismic casualty is subject to various factors. For a certain trapped person, the injury will develop gradually, depending on the trap surroundings, the initial injury state and the physique of that person. In view of this, the concepts of Index of Seismic Casualty and State Function of Seismic Casualty are set up for quantitative and dynamic analysis.

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First, like the division of structural damage level, the casualty injury level is divided into five ranks: Not Injured on the Whole; Slightly Injured; Moderately Injured; Seriously Injured; Dying or Dead. And, like structural damage index, an index of seismic casualty is assigned to each rank or division, with its value between 0 and 1.

Second, the injury state of the trapped person develops under certain conditions, which include the initial injury state, trap surroundings, rescue level and individual physique of the trapped. A function is used to express such development:

$$C(t) = (C_0^{1/n} + S_0\, t)^n \qquad (1)$$

Where: C_0:index of initial injury, C_0 [0,1]

S_0:coefficient of trap surroundings, S_0 [0.004,0.1], the higher value it is, the worse trap surroundings will be;

n: attenuation index of individual physique, n[1.0,3.0], the higher value it is, the worse physique the trapped will has.

Through two-dimensional and three-dimensional parameter analysis (Zhao Zhendong, et al., 2000), it can be shown that among three factors S_0, C_0 and n, S_0 affect the value of $C(t)$ the most.

INITIAL CASUALTY MATRIX

The State Function of Seismic Casualty is concerned with injury development process of a certain trapped person, but current earthquake damage prediction is based on group analysis of structural damage matrix. Therefore, it is essential to integrate them with each other in the assessment. For this, the concept of Initial Casualty Matrix is introduced. To a large extent, whether the seismic casualty is heavy or not during destructive earthquakes depends on the level of structural damage. It is necessary and very natural to relate structural damage level with injury rank. The structural damage matrix currently in use is a probability matrix of five damage levels under certain earthquake intensity; it is also possible to establish a probability matrix of five injury ranks under certain structural damage level, if there are definitions of injury ranks available. Such matrix varies from time to time, for instance, from the moment of earthquake occurrence, t_0 , to a moment of successive rescue, t_s. But for a certain structure and its damage level, the initial casualty matrix is definite. The collapse pattern and process of one structural type differ from that of the other. Therefore, each type of structure has an initial casualty matrix of its own. As an example, table 1 shows the form of initial casualty matrix.

Table 1 Initial Casualty Matrix

Structural Damage Level	Injury Rank / Injury Cause	C_1 [0,0.1] Not injured on the Whole	C_2 [0.1,0.3] Slightly Injured	C_3 [0.3,0.6] Moderately Injured	C_4 [0.6,0.9] Seriously Injured	C_5 [0.9,1.0] Dying or Dead
Intact on the Whole (j=1)	Non-structural Damage	$P(C_{1\|j=1})$	$P(C_{2\|j=1})$	$P(C_{3\|j=1})$	$P(C_{4\|j=1})$	$P(C_{5\|j=1})$
Slightly Damaged (j=2)		$P(C_{1\|j=2})$	$P(C_{2\|j=2})$	$P(C_{3\|j=2})$	$P(C_{4\|j=2})$	$P(C_{5\|j=2})$
Moderately Damaged (j=3)		$P(C_{1\|j=3})$	$P(C_{2\|j=3})$	$P(C_{3\|j=3})$	$P(C_{4\|j=3})$	$P(C_{5\|j=3})$
Seriously Damaged (j=4)		$P(C_{1\|j=4})$	$P(C_{2\|j=4})$	$P(C_{3\|j=4})$	$P(C_{4\|j=4})$	$P(C_{5\|j=4})$
Ruined (j=5)	Non-trapped	$P(C_{1\|NTR})$	$P(C_{2\|NTR})$	$P(C_{3\|NTR})$	$P(C_{4\|NTR})$	$P(C_{5\|NTR})$
	Trapped	$P(C_{1\|TR})$	$P(C_{2\|TR})$	$P(C_{3\|TR})$	$P(C_{4\|TR})$	$P(C_{5\|TR})$

THE DYNAMIC METHOD OF ASSESSING SEISMIC CASUALTY

1) Distribution of Seismic Trap Surroundings for the Trapped

It has been pointed out that, in case that the Initial Injury Index $\boldsymbol{C_0}$ is given, the trap surroundings $\boldsymbol{S}$ weighs more than the attenuation index of physique $\boldsymbol{n}$. So, distribution of Trap Surroundings $\boldsymbol{S}$ needs to be analyzed. It is obvious that the trapped of each injury rank C_m are in different trap surroundings, favorable or not. According to numerical simulation analysis in Ref. [2], the trap surroundings $\boldsymbol{S}$ can be divided into several classes (see Table 2).

Table 2 Division of Trap Surroundings

S	S_1	S_2	S_3	S_4	S_5
Range	[0.004,0.006]	[0.006,0.01]	[0.01,0.02]	[0.02,0.04]	[0.04,0.10]

It should be noticed that the above five divisions of S_1 are not equal, for the influence of $\boldsymbol{S}$ on $\boldsymbol{C}$ is nonlinear.

If $\boldsymbol{S}$ is of Normal Distribution N(μ,σ) or Distribution B(a,b), then the probability value of S_l can be obtained it is simply the proportion of S_l for each C_m. Besides, the expected value of S_l in each division can also be obtained and put into Eq.(1) for calculation. In fact, the trap surroundings (including the factors such as degree of burial, temperature, humidity, effect of aftershocks) vary with the elapse of time. For convenience, it is assumed that $\boldsymbol{S(t)= S_0}$. Thus, in case that $\boldsymbol{S}$, $\boldsymbol{C_0}$ and $\boldsymbol{n}$ is given, the injury of the trapped develops mainly with time $\boldsymbol{t}$.

By use of the distribution of trap surroundings, the structural damage matrix and initial casualty matrix, the number of the trapped when S_l and C_m take different values can be obtained:

$$NTR_{ml}=NTR \cdot P(C_m) \cdot P(S_l) \qquad (2)$$

Where: $P(C_m) \cdot P(S_l)$ can be understood as the proportion of the trapped under C_m and S_l condition.

2) Distribution of the Trapped Who Are Rescued at Different Time Point

After the distribution of $\boldsymbol{S}$ and $\boldsymbol{C_0}$ has been determined, it is possible to assess the injury state development of the trapped by Eq. (1). With the elapse of time from. t_0 to t_s(s=1,2,…), C_{ml} moves to C_{mlts}. In other words, for the trapped person who has an initial injury level C_m and is under S_l trap surroundings, the injury state will move to C_{mlts} , and number of such trapped people is R_{mlts}:

$$R_{mlts} = R_{ts} \cdot P(C_m) \cdot P(S_l) \qquad (3)$$

Where: R_{ts} is the total number of the trapped rescued at the time point t_s in stricken areas

In order to offer helpful information for post- seismic rescue activity, i.e., to determine the total number of people rescued at the time t_s and give their distribution over different injury levels. Table 3 gives the process of calculation, taking the initial state to be C_2 as an example.

Table 3 Dynamic Assessment Process of the Distribution of the Trapped When Rescued

C_0	C_1	$C_0=C_2$ $P(C_2)$					C_3	C_4	C_5
S_0	…	S_1	S_2	S_3	S_4	S_5	…	…	…
$P(S_l)$		$P(S_1)$	$P(S_2)$	$P(S_3)$	$P(S_4)$	$P(S_5)$			
$P(C_m)P(S_l)$ m=1,2,3,4,5 l=1,2,3,4,5		$P(C_2)*P(S_1)$	$P(C_2)*P(S_2)$	$P(C_2)*P(S_3)$	$P(C_2)*P(S_4)$	$P(C_2)*P(S_5)$			
t_1 (R_{t1})	…	$\boldsymbol{C_{2l}(t) = (C_2^{1/n} + S_l\, t)^n}$ **t=** $t_{1\text{-}0}$					…	…	…
		C_{21t1}	C_{22t1}	C_{23t1}	C_{24t1}	C_{25t1}			
		$R_{21t1}= P(C_2) *P(S_1)* R_{t1}$	$R_{22t1}= P(C_2) *P(S_2)* R_{t1}$	$R_{23t1}= P(C_2) *P(S_3)* R_{t1}$	$R_{24t1}= P(C_2) *P(S_4)* R_{t1}$	$R_{25t1}= P(C_2) *P(S_5)* R_{t1}$			
t_2 (R_{t2})	…	$\boldsymbol{C_{2l}(t) = (C_2^{1/n} + S_l\, t)^n}$ **t=** $t_{2\text{-}0}$					…	…	…
		C_{21t2}	C_{22t2}	C_{23t2}	C_{24t2}	C_{25t2}			
		$R_{21t2}= P(C_2) *P(S_1)* R_{t2}$	$R_{22t2}= P(C_2) *P(S_2)* R_{t2}$	$R_{23t2}= P(C_2) *P(S_3)* R_{t2}$	$R_{24t2}= P(C_2) *P(S_4)* R_{t2}$	$R_{25t2}= P(C_2) *P(S_5)* R_{t2}$			
t_s (R_{ts})	…	… … … … …					…	…	…

Here, two assumptions are made:
a) Probability of S_l(l=1,2,3,4,5) under each C_m (m=1,2,3,4,5) is equal, e.g. , $P(S_2|C_0=C1)= P(S_2|C_0=C5)$
b) In stricken areas, how many trapped can be rescued at certain time point t_s depends not only on the local main construction type, but also on how well the rescue power is organized after quake and how well the public is aware of disaster preparedness before quake. In view of this, it is difficult to give a universal R_{ts} by a unified model or method before earthquake.

Although every C_{mlts} has its own numerical value, it must fall into one of the intervals of C_1, C_2, C_3, C_4 and C_5, C_{mlts}-C_m(m=1,…,5). To sum up the R_{mlts} values corresponding to the same interval C_m, the actual distribution of the number of trapped under different injury levels, when rescued, can be obtained. Such summation can be done at different time points.

APPLICATION OF DYNAMIC METHOD OF SEISMIC CASUALTY ASSESSMENT

1) the Tangshan Earthquake Data

Table 4 gives the data of the Tangshan Earthquake quoted from K. Shiono and F. Krimgold (1992) and "Tangshan Nowadays" (1996). The data is about the urban areas of Tangshan only.

Table 4 Data of the Tangshan Earthquake (Urban Areas)

Tangshan Earthquake	Occurring Time Point: 03:42-1976.7.28 Magnitude: 7.8M Depth: 11Km Epicenter Position: N-$39^0$38' E-$118^0$11'			
Urban Area 66 Km^2	Area of Intensity X		30%	19 Km^2
	Area of Intensity XI		70%	47 Km^2
Urban population:1,196,800	During Quake	Dead	149,000	
		Seriously Injured	> 80,000	
		Slightly Injured	> 80,000	
Urban Residential Area 8,941,000 m^2	Multi-story Masonry		20%	1,788,200 m^2
	Low-strength Masonry (including one-story masonry)		80%	7,152,800 m^2
Structural Damage Matrix of Multi-story Masonry	Structural Damage Level		¢ú	¢û
	Intact on the Whole(j=1)		0.006	0.003
	Slightly Damaged (j=2)		0.05	0.015
	Moderately Damaged (j=3)		0.065	0.047
	Seriously Damaged (j=4)		0.237	0.141
	Ruined (j=5)		0.642	0.794
Structural Damage Matrix of Low-strength Masonry	Structural Damage Level		¢ú	¢û
	Intact on the Whole(j=1)		0	0
	Slightly Damaged (j=2)		0	0
	Moderately Damaged (j=3)		0.02	0.005
	Seriously Damaged (j=4)		0.20	0.075
	Ruined (j=5)		0.78	0.92

2) Application of Dynamic Assessment Method

2-1) Determination of the Distribution of Local Trap Surroundings

It is assumed that local trap surroundings do not change from quake occurrence to subsequent rescue activity, and their distribution can be expressed by a certain function, which is convenient for determining the percentage of every level $\boldsymbol{S_l}$. In the Tangshan earthquake, earthquake-induced fire and the climate then did not have any evident negative effects on trap surroundings. Even though aftershocks gave some interference to the rescue effort, $\boldsymbol{S}$ can still be regarded as being independent of the geography in the urban areas. Besides, most of the ruined buildings were low-strength masonries which were of light construction material. Owing to these reasons, it can be assumed that P(S1)/P(S5)=10:1 and the trap surrounding of the best level S_l make up 15% of the total. Then, percentages of the other four levels are obtained from β distribution function. Fig. 1 shows the distribution.

When the distribution of initial injury level C_m is known, using the distribution of S_l, the number of the trapped corresponding to different C_{ml} values at the time of origin of the Tangshan earthquake, t_0, can be obtained. Table 5 is the result obtained from the structural damage matrix and initial casualty matrix (only that of multi-story masonry is given as an example). Because the Tangshan earthquake broke out before dawn, the indoor rate of people may be as high as 98%. The trapped rate was 73.5% in intensity ¢úareas and 78.35% in ¢û areas (Shiono, K. and Krimgold, F., 1992).

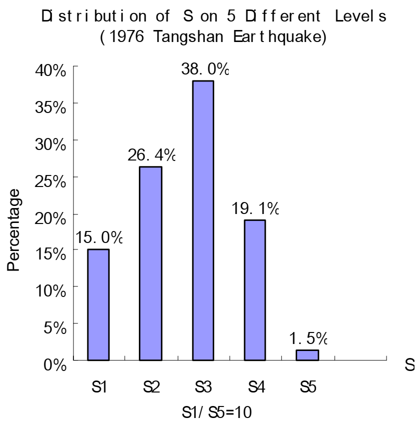

Figure 1a Percentage Histogram of 5 Levels of *S*

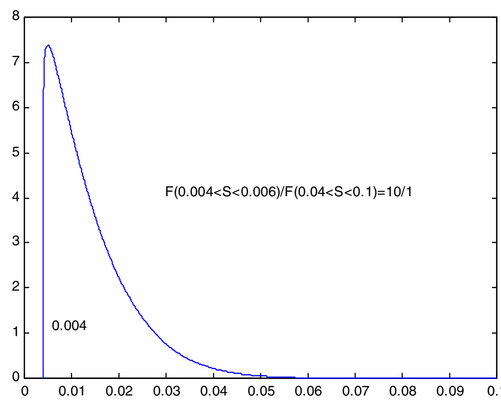

Figure 1b Beta Density Curve of *S*

Table 5 Initial Casualty Distribution of Multi-story Masonry during the Tangshan Earthquake (×10,000)

Structural Damage Level	Injury Rank / Injury Cause	C_1 [0,0.1]		C_2 [0.1,0.3]		C_3 [0.3,0.6]		C_4 [0.6,0.9]		C_5 [0.9,1.0]	
Intact on the Whole (j=1)	Non-structural Damaged Induced	0.092		0		0		0		0	
Slightly Damaged (j=2)		0.598		0.0004		0		0		0	
Moderately Damaged (j=3)		1.216		0.012		0.0008		0.0001		0	
Seriously Damaged (j=4)		3.738		0.196		0.035		0.01		0.004	
Ruined (j=5) TR10=73.5% TR11=78.35%	Non-trapped	0.238		3.035		0.69		0		0	
		S_1	0.67	S_1	0.75	S_1	0.43	S_1	0.13	S_1	0.06
		S_2	1.18	S_2	1.32	S_2	0.75	S_2	0.23	S_2	0.10
		S_3	1.71	S_3	1.91	S_3	1.09	S_3	0.33	S_3	0.14
		S_4	0.86	S_4	0.96	S_4	0.54	S_4	0.16	S_4	0.07
		S_5	0.07	S_5	0.08	S_5	0.04	S_5	0.01	S_5	0.01
		4.49		5.02		2.85		0.86		0.37	

2-2) Injury Development

In the expression of state function of seismic casualty $C(t) = (C_0^{1/n} + S_0\, t)^n$, C_0 and S_0 are now available, n is taken to be 1.6; hence $C(t)$ varies with t only. At the rescue time t_s after quake, the specific value of $C(t)$

can be calculated; it must fall into one of the intervals from $\boldsymbol{C_1}$ to $\boldsymbol{C_5}$. Table 6 shows the variation of $\boldsymbol{C_{ml}(t)}$ with t_s (s=1,2,3, …,8); it corresponds to the twenty-five combinations of $\boldsymbol{C_m}$ ***(m=1,2,3,4,5)*** and $\boldsymbol{S_l}$ (l=1,2,3,4,5). It can be seen from the table that for the trapped of initial injury rank C_1 (not injured on the whole) and under best trap surroundings S_1, the injury index value will change to 0.63 even in the fifth day; if rescued at that time the trapped is sure to survive. Such an analysis tallies with the on-site investigation during the Tangshan earthquake. The underlined data suggest that $\boldsymbol{C(t)}$ is approaching 1.0, which means that the trapped is going to die.

Table 6 Changing of Injury Index C ($C(t) = (C_0^{1/n} + S_0\, t)^n$) n=1.6

t_0	C_0	C_1					C_2					C_3					C_4					C_5				
	S	S_1	S_2	S_3	S_4	S_5	S_1	S_2	S_3	S_4	S_5	S_1	S_2	S_3	S_4	S_5	S_1	S_2	S_3	S_4	S_5	S_1	S_2	S_3	S_4	S_5
T=3h		0.05	0.06	0.07	0.09	0.13	0.20	0.20	0.22	0.26	0.31	0.43	0.44	0.46	0.51	0.58	0.74	0.75	0.78	0.83	0.92	0.97	0.98	1.00	1.00	1.00
T=6h		0.06	0.07	0.10	0.15	0.25	0.21	0.23	0.26	0.34	0.47	0.45	0.47	0.52	0.61	0.77	0.76	0.78	0.84	0.95	1.00	0.99	1.00	1.00	1.00	1.00
t=12h		0.08	0.10	0.16	0.29	0.56	0.24	0.27	0.35	0.52	0.84	0.49	0.53	0.63	0.84	1.00	0.80	0.85	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00
t=24h		0.12	0.17	0.32	0.68	1.00	0.30	0.37	0.55	0.97	1.00	0.56	0.65	0.87	1.00	1.00	0.89	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
T=2d		0.22	0.36	0.74	1.00	1.00	0.43	0.60	1.00	1.00	1.00	0.72	0.93	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
T=3d		0.34	0.58	1.00	1.00	1.00	0.58	0.87	1.00	1.00	1.00	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
T=4d		0.47	0.85	1.00	1.00	1.00	0.74	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
T=5d		0.63	1.00	1.00	1.00	1.00	0.92	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

2-3) Final Results of Dynamic Assessment for the Tangshan Earthquake

Since all the trapped, whether alive or not when rescued., were extricated from trap surroundings from t=0 to t=5d, the number of the trapped of level $\boldsymbol{C_m}$ and $\boldsymbol{S_l}$ can be calculated through from $R_{mlts} = R_{ts} \cdot P(C_m) \cdot P(S_l)$. Then the extricated, $\boldsymbol{R_{ts}}$ in total are divided into five ranks in accordance with their injury $\boldsymbol{C_m}$(m=1,…,5) for adding up. Table 7 shows the result of dynamic assessment including the final distribution of casualties caused by both non-structural damage and structural damage.

Table 7 Results of Dynamic Assessment of Seismic Casualty (the Tangshan Earthquake)

Structural Damage Level	Injury Cause	Injury Rank					
		C_1: Not Injured the Whole	C_2: Slightly Injured	C_3: Moderately Injured	C_4: Seriously Injured	C_5: Dying or Dead	
Intact on the Whole (j=1)	Non-structural	17.74	0.75	0.13	0.04	0.0135	0
Slightly Damaged (j=2)							0
Moderately Damaged (j=3)							0
Seriously Damaged (j=4)							0.0135
Ruined (j=5)	Non-trapped	2.08	16.97	3.30	0	0	
	trapped	12.59	21.44	18.67	8.18	15.39	
Total 1,172,900		32.40	39.16	22.10	8.22	15.41	
Percentage		27.62%	33.39%	18.84%	7.01%	**FR: 13.13%**	

3) Applicability of Dynamic Assessment Method

It can be seen from assessment results that the dynamic assessment method has a good applicability.

3-1) Comparison of Survivability Rate of the Rescued

Survivability of the rescued given by this paper can be compared with that provided by Liu Huixian (1985) (see Fig.2). It is obvious that the comparison is satisfying, except that between the results for t=48 hours. Such difference can be explained by the strengthening of rescue power then or improper statistics.

3-2) Comparison of the Numbers of the Dead and the Seriously Injured

From the calculated results shown in Table 7, the numbers of the dead and the seriously injured during the Tangshan earthquake are 154,100 and 81,200 respectively; there are very close to the original data given in table 5 (149,000 and 80,000). The relative error (being 3.4% for the dead) is low enough; this means that the dynamic assessment method is of a good precision when applied to destructive earthquakes.

3-3) Comparison of Fatality Rate under Structural Damage Level j=5 (Ruined)

The calculated fatality rate is 18.53% for multi-story masonry and 14.98% low-strength masonry. Compared with those statistical data from Zhao Zhendong (1998), the fatality rate is 25% for brick masonry (including one-story and multi-story), 15% for adobe masonry, 17.5% for stone masonry, the difference is small as well.

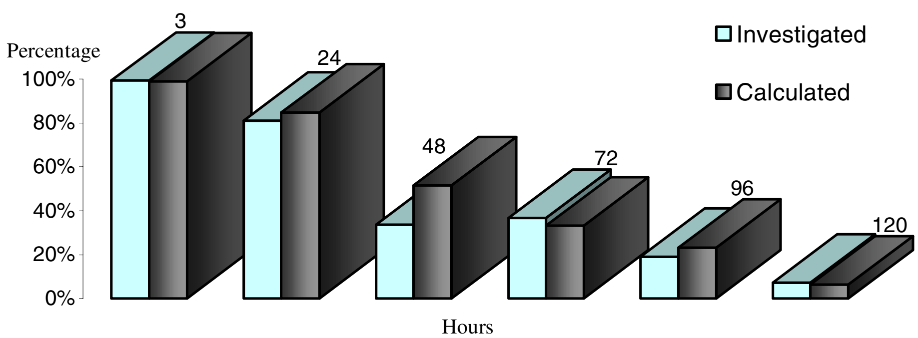

Figure 2 Comparison of Survivability Rate

4) Discussion on the Results of Dynamic Method

Up to the end of first-day rescue activity, the survivability rate of the trapped can be as high as 84.72%. But at the end of the second day, this rate dropped down 50%. Hence the rescue activity of the first two days is of utmost important.

It should be noted that among the factors responsible for the heavy casualty of the Tangshan earthquake, are of course the high magnitude of the quake and its special time of origin; nevertheless, in case that the construction types and their initial casualty matrix are given, the cause that led to heavy casualties could only be the high probability value of the two damage levels: seriously damaged and ruined. Why? The earthquake resistance of low-strength masonry and non-resistant brick masonry in Tangshan areas is very low. Though the Northridge and Loma Prieta earthquakes, it is evident that the higher earthquake resistance the buildings have, the lower the seismic casualties will be.

CONCLUSION

To sum up, some conclusions can be drawn from the above analysis.

1) The injury development of the trapped during earthquakes is a changing process that is subject to many factors, but previous studies in this field are mostly of after-effect character. The dynamic assessment method in this paper has overcome this shortcoming and broadened the scope of research thinking in this field.
2) Life vulnerability analysis (dynamic) is different from structural vulnerability analysis (generally static). A key link is often ignored by previous assessment methods, i.e., the injury development, which is directly related to the timely and effective rescue activity, dissemination of disaster prevention knowledge, and so on. In fact, this key link is just what the dynamic assessment method studies.
3) In seismic life vulnerability analysis, some humanist factors are involved. After quantitative analysis of these factors, by use of some probability distribution functions, the initial casualty matrix is introduced to link up structural damage matrix with the state function of seismic casualty. So the entire

dynamic assessment process could be carried out on quantitatively. Final results of the Tangshan earthquake as a case show that the introduction of these functions enables quantitative assessment and meet the reality of earthquake hazard.

4) The structural damage level reflects earthquake resistance of structure. The reassessment results of the Tangshan earthquake prove that earthquake resistant of buildings determines the level of seismic casualty. In order to reduce seismic casualty, a key step is to raise the earthquake resistance of buildings and reinforce or retrofit current constructions.

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