PERFORMANCE EVALUATION SYSTEM IN ENGINEERING MATTERS: SYSTEMATIC AND THEORETICAL APPROACH TO HUMANITY

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ABSTRACT

As the systematic approach to engineering matters, the **performance evaluation system** is proposed and examined theoretically by using the mathematical model. The **systematic and theoretical approach to humanity** is described. In the long history of human activity, engineering, culture, tradition, customs, life style, language have been formed gradually based upon politics, economics, natural and social environments. In usual, facility (F) behaves and performs a certain interaction (I) under some environments (E). This general phenomenon (physics/chemistry) is due to nature law and also applied to general social phenomenon and human activity. Above F,E,I are considered to be primary elements of the basic system V(F,E,I).The performance of V(F,E,I) is evaluated as a result of phenomenon. As the rating index (p), five elements are defined: time(t), space(x),money(m), humanity(h), quality(q). The basic system V(F,E,I) is expressed in form of V(t,x,m,h,q) because of having the rating index built-in. The performance evaluation system is formulated by the mathematical model (partial differentiation form)of δV(F,E,I)/ δp.

By using a model of the existing bridge, the **basic system V(F,E,I) of steel bridge and their performance evaluation** are simulated by the mathematical model. Facility F, environment E and interaction I elements of the basic system V(F,E,I) of the steel bridge are organized and each hierarchy is built in detail. They are closely related to the description/articles of the specification in edit and design use. The methodology of constitution and systematization of the specification is proposed. The sample bridge has been awarded as one of the best bridge of the year by JSCE in 2012. The performance evaluation clarifies why it is worthwhile and selected. **Systematic approach to engineering matters and humanity** are discussed. As the two-dimensional（X,Y）problem, the **expression method of block diagram** is described. The X-Y axes should be orthogonally designated by independent phenomenon each other. Based upon the nature law, Pareto distribution and the potential energy reserved theory, three problems are examined; 1)Risk management, regional disasters control, 2)Fracture/fatigue problems of the shear panel dampers and 3) The PM (performance/maintenance) theory of human activity.

Keywords: performance evaluation system, rating index, primary/secondary evaluation, bridge system, nature law, potential energy reserved theory

1.Basic system and performance evaluation system

1-1 Basic System (Fig-1)

In usual, facility (F) behaves and performs a certain interaction (I) under some environments (E). This general phenomenon (physics/chemistry) is due to nature law and also applied to a general social phenomenon and human activity. The system V(F,E,I)is expressed in 3- dimensional form in 3-dimensional axes(F,E,I).Above F,E,I are considered to be primary elements of the basic system V(F,E,I). The phenomenon is classified into two categories:1)independent phenomenon,2)subordinate phenomenon. The bridge F consists of a number of members and pieces which are connected together and assembled into several blocks at yard (**Fig-3**). The bridge is systematized by tree structures of subordinate/common parts. On the other hands, environment E and interaction I are expressed by the independent phenomenon which is mutually exclusive each other. The basic system V(F,E,I) and the performance system P are expressed by 4-dimensional form.

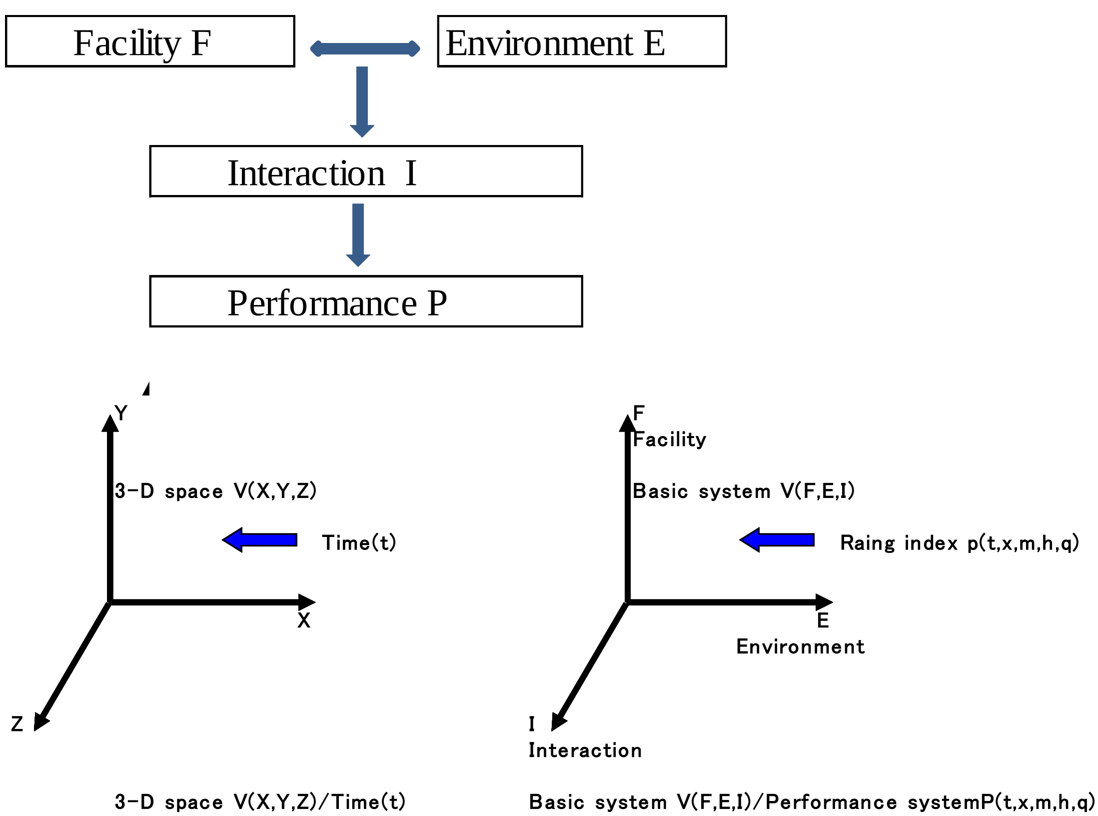


Fig-1 Basic system V(F,E,I) and Performance system P

1-2 Performance System and rating index

The performance of V(F,E,I) is evaluated as a result of phenomenon. As rating index (p), five elements are defined; time(t), space(x),money(m), humanity(h), quality(q). Space(x) is visible and materialistic product in natural environment. On the other hand, time(t),money(m),humanity(h) and quality(q) are non-visible and idealistic product in social environment as a result of human activity. The basic system V(F,E,I) is expressed in form of V(t,x,m,h,q) because of having rating indexes built-in. Primarily, it is revised to organize the basic system V(F,E,I) . Secondary, the performance evaluation system is formulated by mathematical model (partial differentiation form) of $\delta V(F,E,I)/\delta p$.

1-3 Basic system V(F,E,I) and performance system P (Table-1)

They are available in many fields.**Table-1** shows a variety of engineering and social problems. In any cases, safety and serviceability are commonly important matters, because they are always associated with human activity.

Table-1 Examples in many fields: Basic system V (F, E, I) and performance system P

Facility	Environment	Interaction	Performance
structural system	loading	physical behaivor	deformation/stress
steel structure	natural environment	corrosion	serviceability/fracture
building	social environment	sale/buy	Economic/investment effect
observation tower	town/city scape	human activity	serviceability/security
house	narrow quarters	fire accident	disaster/risk prevention
car	highway	driving	safety/serviceability
software	computer	instruction execution	capacity/speed

1-4 Primary/secondary evaluation (Table-2)

1)Primary evaluation: $\delta V/\delta p$ (gradient/grade), quick/slow (t), large/small (x), tough/fragile, strong/weak (q), beautiful/dirty, bright/dark (h), expensive/cheap, rich/poor (m).
2)Secondary evaluation:$\delta^2 V/\delta p^2$ (acceleration/inertia/potential), life evaluation (t), spread characteristics, broad spectrum evaluation (x), safety, reliability evaluation (q), public opinion, reputation, use-related evaluation (h), money making characteristics, economic evaluation(m).
3)Sequence order of evaluation time: The decision making is handled depending on a situation to develop one by one. The conclusion highly depends on time processing.

Table-2 Primary and secondary evaluation by partial differentiation form

	primary evaluation $\delta V/\delta p$		secondary evaluation $\delta^2 V/\delta p^2$	
index	form	gradient/grade	form	acceleration/inertia/potential
time t	$\delta V/\delta t$	quick/slow,new/old	$\delta^2 V/\delta t^2$	life time,life deterioration, persistence
space x	$\delta V/\delta x$	large/small,long/short	$\delta^2 V/\delta x^2$	broad spectrum, regionalism
money m	$\delta V/\delta m$	expensive/cheap,rich/poor	$\delta^2 V/\delta m^2$	economy,moneymaking characteristics
humanity h	$\delta V/\delta h$	beautiful/dirty,bright/dark	$\delta^2 V/\delta h^2$	public opinion,reputation,serviceability
quality q	$\delta V/\delta q$	tough/fragile,strong/weak	$\delta^2 V/\delta q^2$	safety,reliability

1-5 Multifarious evaluation(Table-3)

Multifarious evaluation $\delta^2 V/\delta p_1 \delta p_2$: The system V is revised from different viewpoints. $\delta^2 V/\delta m \delta t$: change of stock prices. $\delta^2 V/\delta h \delta t$: reputational future risk in time history. Sequence order of evaluation: $\delta^2 V/\delta h \delta t$ may or may not result in the same result of $\delta^2 V/\delta t \delta h$. When $\delta^2 V/\delta p_1 \delta p_2$ is equivalent to $\delta^2 V/\delta p_2 \delta p_1$, the system V is considered to be perfect system in global/eternal sense. In Table-3, when $\delta^2 V/\delta t \delta h$(historical/aesthetic appreciation) is equivalent to $\delta^2 V/\delta h \delta t$ (change of mind, media bias), the system is considered to be persistent/perfect, which is recognized to be true by anyone and in anytime.

Table-3 Multifarious evaluation by partial differentiation form

	multifarious evaluation	δ2V/δp1δp2
index	form	multilateral/different viewpoints.
time t	$\delta^2 V/\delta t \delta h$	historical/aesthetic appreciation
space x	$\delta^2 V/\delta x \delta t$	world heritage,velocity/speed
money m	$\delta^2 V/\delta m \delta t$	currency, change of stock price
humanity h	$\delta^2 V/\delta h \delta t$	change of mind,media bias
quality q	$\delta^2 V/\delta q \delta t$	quality deterioration

2. Basic System V(F,E,I) of the steel bridge and Performance evaluation system

2-1 F, E, I elements: The Awa Shirasagi Bridge (Fig-2)

The Awa Shirasagi Bridge is used as a model for system explanation. It has been constructed during 2000~2012 with the construction cost of 25billion yens.

1) Facility: Rigid frame girders (716m), cable stayed girders (575m), bridge dimensions (1291m*(26.3~32.3m)), 4 lanes (highway) + pedestrians (both sides).The centre span girder(260m) is suspended by a single stayed cable in parallel from low rise towers, which is newly called there as egret type cable stayed girders.

2) Environment: At the Yoshino river (width 1000m), crossing at the mouth to ocean in Tokushima Japan, traffic service (60 km/h), vehicles/day (25,000). Environmental consideration to the tideland areas and coming flying birds (white egrets in blue sky).

3) Interaction: Static and dynamic behaviour due to highway loading, earthquake and strong wind. Aerodynamic stability has been required against the ocean wind.

2-2 Facility, Environment, Interaction: Steel Bridge system V(F,E,I) (Table-4,5,6,7)

It is revised to organize the basic system V (F, E, I), then each hierarchy (F) is built in detail. Each element (E, I) should be mutually exclusive and independent phenomenon each other in mathematical sense. They are closely related to the description/articles of specification/codes (AISC, AASHTO, Japanese Design Specifications for Highway Bridges).

Fig-2 The Awa Shirasagi Bridge: Facility F(cable stayed bridge), Environment E(in traffic service)

Table-4, 5, 6 show each element of the bridge system V (F, E, I). **Fig-3** shows hierarchy of F1 (truss) .The truss bridge is consisted of several blocks which have been assembled by members and pieces as tree structures.

Facility F (Table-4)

1) F1 deals with independent phenomenon and is classified as specialized fields associated with professional business and industrial groups (car, ship, building, bridge).They are expressed in parallel order.

2) F2, F3~F8 deal with the subordinate phenomenon and are classified as common fields associated with the material and machinery industry (steel maker, concrete maker).They are expressed by tree structures forming hierarchy in series order.

Table-4 Facility elements of Bridge System V (F, E, I)

		Facility F (δV/δF)	Japanese Design Specifications for Highway Bridges
F1	type	plate girder,commposite slab,truss,arch,pipe	plate girder,truss,arch,pipe,rigid frame ,cable
		tower,rigid frame	
F2	member	beam,column,frame,bracing,slab,stringer,cable	bracing,lateral bracing,floor system,slab
F3	material	steel:plate,pipe,bar,connections	steel,concrete
		concrete:cement,sand,gravel,mixtures	
F4	connection	welding,bolt,rivet	HTB,welding,pin
F5	pavement	steel deck,concrete slab	raod pavement
F6	joint	expanssion,bearing	expantion,bearing
F7	accessary	drain,fence,guardrail,noise shelter ,steps	drain,fence,guardrail,inspection facility
F8	hazard	earthquake,wind,fire	stopper,damper,flap
	prevention		

$\delta V/\delta F = \delta V/\delta F.\ \delta F/\delta F1 + \delta V/\delta F.\ \delta F/\delta F2 + \delta V/\delta F.\ \delta F/\delta Fn$

block	member	piece
F1 Truss	F11 upper chord F12 lower chord F13 web F14 vertical F15 diagonal F16 portal F17 stringer F18 beam	F111 flange F112 web F113 diaphragm F114 bolt F115 hand hole F116 step

Fig-3 Hierarchy of Facility F1:Truss bridge

Environment E (Table-5)

1) E1(climate, earth, water, sea) are thought to be independent phenomenon locally, but globally weather depends on the earth astrological phenomenon in four seasons .E1 are mutually interacted as subordinate phenomenon.

2) Importance of each E1 is deeply associated with facility F1 where they are existing in the earth, water, sea and air.

3) The hazard occurs at abnormal condition of E1,and the design bases on abnormal levels of the environments against hazard prevention.

4) E2(social environment) are deeply associated with rating indexes(t,m,x,h,q) as the result of human activity(history, culture, tradition, custom, thinking process). The design depends on the social requirements (what is most important now? ; such as sustainability of natural resources , energy reservation, or cost minimum).

Table-5 Environment elements of Bridge System V(F,E,I)

	Environment E (δV/δE)		Japanese Design Specifications for Highway Bridges
E1	**nature**	climate rain,wind,snow	rain,wind,snow,temperature
		earth earth movement/force,earthquake,volcano	earth pressure, sliding,gravity
		water gravity,floating,uplift,flow,flood	water pressure,float,uplift
		sea wave,current,tide	wave,tide
E2	**social**	rule history,local/gloval	local rule
		country culture,custom,tradition	
		people human activity,urban/rural,bias	noise
E3	**load**	dead load/live load,static/dynamic,braking/collision	dead load,live load,collision,impact
		gravity/uplift/lateral force	gravity/uplift/lateral force,braking
E4	**work**	place yard/site	fablication at yard,construction at site
		labor man/machine,soft/hard,skill/craft	professional qualification,training

$$\delta V/\delta E = \delta V/\delta E.\ \delta E/\delta E1 + \delta V/\delta E.\ \delta E/\delta E2 + \delta V/\delta E.\ \delta E/\delta En$$

Interaction I (Table-6)

1) The interaction deals with natural science (physics/chemistry) based upon nature law by mathematical methods. The results are universally and eternally unique whenever, whichever, wherever, whoever and however they are analysed and synthesized.

2) I1,I2,I3,I4,I5:They are independent phenomenon and expressed in parallel order.

3) I3(analysis model),I5(research methods):They depend on computer and monitoring technology at the present time.

4) Besides, the social interaction is revised how people interact by the performance evaluation.

Table-6 Interaction elements of Bridge System V(F,E,I)

	Interactiotion I (δV/δI)		Japanese Design Specifications for Highway Bridges
I1	**physics**	equilibrium problem(stress/strain)	force/displacement
		eigenvalue problem（stability)	stability,slide,overturning
		boundary problem(propagation)	earthequake ,wave
I2	**failure**	elongation/shrinkage	allowable stress,displacement
		buckling(compression,bifurcation)	buckling
		fracture(ductility,fatigue)	fatigue
I3	**model**	structure,boundary,response,loading	prototype
I4	**corrosion**	painting/coating	painting/coating
I5	**research**	testing, static/dynamic,site/labolatory	static/dynamic test,site/labolatory test
		observation device/instrument	monitoring
		survey/measure soft/hard	survey/measure

2-3 Cause/effect analysis (Table-7)

Primary design（First order analysis）: Bridge (F1 type, F2 member) behaves and performs a certain interaction(I1,I2) under some environments(E3 traffic loads, E1 earthquake loads),then the results are evaluated if safety/ serviceability are satisfactory.

Detailed design (Second order analysis): Members (F11, F12, F13, F1n) of facility F1 are designed in detail, based upon the result of V(F,E,I) analysis.

Table-7 Cause/effect analysis

Partial cause/effect analysis	**δV/δp=δV/δF.δF/δp+δV/δE.δE/δp+δV/δI.δI/δp**
F,E,I elements of V(F,E,I)	**δV/δF, δV/δE,δV/δI**
First order analysis	**δV/δF=δV/δF1+δV/δF2+δV/δFn**
Second order analysis	**δV/δF1=δV/δF11+δV/δF12+δV/δF1n**
Performance evaluation	**δF/δp, δE/δp,δI/δp**
First order analysis	**δF/δp=δF1/δp+δF2/δp+δFn/δp**
Second order analysis	**δF1/δp=δF11/δp+δF12/δp+δF1n/δp**

2-4 Performance evaluation: Function integrated type/function separated type (Fig-4,Table-8)

The system V is classified into function integrated type and function separated type, which results in big influence on the performance evaluation for decision making.

PC Bridge:Function integrated type
(super structure+piers+side wall)
They are constructed together at site.

Cable stayed Bridge:Function separated type
(girder+tower+cable+bearing+side wing+accessary)
They are mainly fablicated and assembled at yard.

Fig-4 Bridge type: Function integrated type(A) /separated type(B)

In case of the function integrated type, the performance evaluation is independent of sequence order of evaluation. Reversely in case of function separated type, it is dependent on sequence order of evaluation. It requires what is most important now in the social environments.

Table-8 Performance evaluation: Function integrated /separated type

	Function integrated type	Function separated type
System	V(F)=V(F2,F3,F4,Fn)=V(t,m,x,h,q)	V(F)=F2(m,q)+F3(m,x)+F7(t,h)+F8(q)
Perfomance evaluation	1)aesthetic /monument view(h) $\delta V/\delta p=V(t,m,x,h,q)/\delta h=V(t,m,x,q)$ 2)economy/serviceability viw(m) $\delta V/\delta p=V(t,m,x,h,q)/\delta m=V(t,x,h,q)$ 3)quality/safety /hazard prevension view(q) $\delta V/\delta p=V(t,m,x,h,q)/\delta q=V(t,m,x,h)$ 4)scale/site view(x) $\delta V/\delta p=V(t,m,x,h,q)/\delta x=V(t,m,h,q)$	1)aesthetic/monument view(t,h) $\delta^2 V/\delta h\delta t=F7$ 2)economy/serviceability viw(m) $\delta V/\delta m=F2+F3$ 3)quality /safety/hazard view(q) $\delta V/\delta q=F2+F8$ 4)scale /site view(x) $\delta V/\delta x=F3$
Result	independent of sequence of evaluation	dependent on sequence of evaluation
Merit	useful for simlicity of total design	useful for cost analysis,standard design
Maintenance	free	exchange by new parts

2-5 Performance evaluation: The Awa Shirasagi Bridge

Bridge B (**Fig-3**,The Awa Shirasagi Bridge) is one of the best bridge of the year awarded by JSCE in 2012. The requirements for the best selection are considered to satisfy the following performance evaluation (**Table-2,3**).

1)Primary evaluation(gradient/grade): $\delta F/\delta t$=new/old(the newest), $\delta F/\delta x$= large/small(larger),$\delta F/\delta m$=rich/poor(gorgeous),$\delta F/\delta h$=beautiful/dirty(great/beautiful).

2)Secondary evaluation(acceleration/inertia/potential):$\delta^2 F/\delta h^2$ =public opinion, reputation, $\delta^2 F/\delta x^2$=broad spectrum, $\delta^2 F/\delta t^2$=heritage.

3)Multifarious evaluation:$\delta^2 F/\delta t\delta h$=historical/aesthetic appreciation.

4)Total evaluations: $\delta F/\delta p+\delta^2 F/\delta p_1\delta p_2+\Sigma\delta^2 F/\delta p^2$

=power/impact to promote engineering technology for the next generation.

2-6 Methodology of constitution and systematization of specifications: Design use

The performance evaluation system is effective to organize the new specifications: Performance evaluation :$\delta V/\delta p=\delta V/\delta F.\delta F/\delta p+\delta V/\delta E.\delta E/\delta p+\delta V/\delta I.\delta I/\delta p$ (**Table-7**).

A. F,E,I elements of the system V(F,E,I) :$\delta V/\delta F$, $\delta V/\delta E$,$\delta V/\delta I$ **(F,E,I codes,Table-4,5,6)**.
B. F,E,I performance (quality)evaluation :$\delta F/\delta q$, $\delta E/\delta p$,$\delta I/\delta p$ (**P code**,**Table-2,3**).
Above A specifies the rule articles of facility, environment and interaction. Above B specifies the rule articles of quality(q)/safety/serviceability. The system V(F,E,I) is

expressed in 3-dimensional form using 3-dimensional axes(F,E,I) and easily converted to 2-dimensional surfaces in form of articles matrix. Looking at the articles matrix, it is possible to revise and update specifications more perfect;1) prevention of the lack of rule articles, 2) exclusion of the overlap articles , and 3) correspondence to an exception articles.

(Example): truss portal F16+earthquake E1+stability I1=**Bridge Fcode (F16,E1,I1)** .After cause/effect analysis by Bridge F codes(F16,E1,I1) , act performance evaluation by **Bridge P code (**q, design criterion/constraints).

2-7 Performance based design: Design method toward design simplicity (F, E, I codes)/ Innovation forward new engineering technology (P code)

1) The performance based design method is effective on the steel bridges of function separated type (**Fig-4 (B)**).

2) It is effective for standard parts design of Bridge facility (F3,F4,F5,F6,F7,F8,**Table-4**), where each function of parts is clearly and independently specified and organized.

3) By standard design, quality (q, safety /serviceability) and size(x, standardization) are evaluated well and good F-parts are supplied with low cost (m, mass production) through timely delivery (t, quick/exchange by new model).The cause/effect analysis will be done in detail and evaluated by P code exactly if required (Risk management **Fig-6**).

4) The performance system innovates better basic system V(F,E,I) and guarantees safety/serviceability at the ultimate states against the abnormal levels of loadings(Failure modes at the ultimate states,**Fig-7,8**). The revised version of P code (design criterion/constraints, quality level, life/maintenance and safety /serviceability) promotes new engineering technology.

3. Systematic approach to engineering matters and humanity: Potential energy reserved theory and block diagram

3-1 Block diagram

Systematic approach to engineering matters and humanity are discussed. As the two-dimensional （X,Y） problem, **block diagram** is used sometimes. It should be orthogonally designated by independent phenomenon each other. In X-Y axes, time(t),space(x), money(m),humanity(h),quality/quantity(q) are usually chosen as the rating indexes which are mutually exclusive and independent phenomenon each other.

3-2 Pareto distribution: Nature law, Zipf's law, shape parameter (Fig-5,Table-9)

A formula of **Zipf's law** by Zeta distribution is given by;
F(m,s,n)=(1/ m^s)/ Σ (1/n^s)   n=1,2,3, N.   When s=1 , F (m,N)=(1/m)/ Σ (1/n)=1/(m* SUM)
SUM= Σ (1/n), N is total number of sampling data.

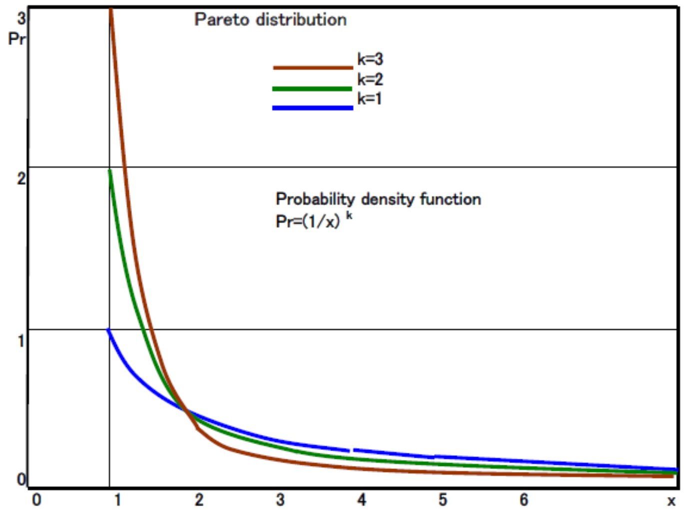


Fig-5 Pareto distribution, Pr= $(1/x)^k$

Pareto distribution Pr（Fig-5） is a continuous probability function. Zipfs law sometimes called the zeta distribution, will be thought of as a discrete counterpart of the Pareto distribution. The shape factor k has some properties: 1) k >1,too active/top heavy type,2) k=1, stable/natural type, the curve(xy=constant) is referred to the **potential energy reserved theory(Fig-6,7,9)**. 3) k<1,reserved/long tail type.

Table-9 Pareto distribution: Nature law and shape parameter k

Probability density function Pr=$(1/x)^k$ ∫ dx/x=log x, k: shape paremeter

k	status	distribution	shape	natural and social environments
k>1	too active	top heavy	sharp &concentration	barrier free, non-constraints, exess competition
k=1	stable	natural	shape of natural logarithm	nature, liberty / equality under justice, fare trade
k<1	reserved	long tail	flat& plain(closed society)	human inactivity, constraints, under development

Pareto distribution is originally used to describe the allocation of wealth and income among individuals. Pareto principle or "80-20 rule" says that 20% of the population controls 80% of the wealth. The rest 80% of the population shares the rest 20% of the wealth. This distribution is not limited to describing wealth and income, but also to many situations in which equilibrium is found in the distribution of the "small" to "large". The following examples are sometimes seen as to be approximately Pareto-distributed.

1) The sizes of human settlements (few cities, many hamlets/village).

2) Hazard disk drive error rates.

3) The values of oil reserves in oil fields.

4) Numbers of species per genus.

5) Sizes of fractured pieces.

6) Sizes of sand particles.

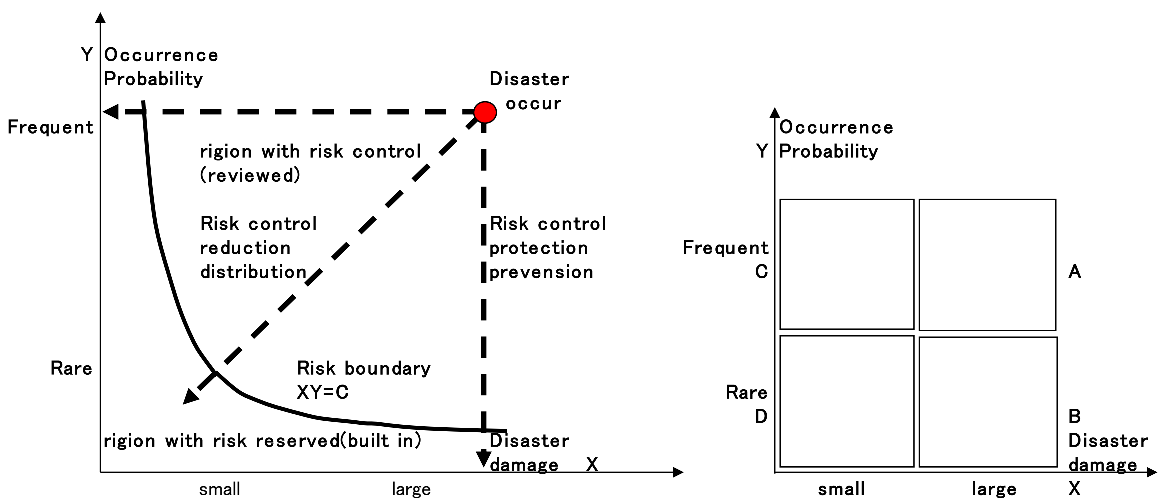
7) Areas burnt in forest fires.

8) Serviceability of large casualty losses for certain lines of business.

9) Annual maximum one-day rainfalls and river discharges.

3-3 Risk management:Regional disaster, risk control, risk diagram, nature law(Fig-6)

A risk diagram (occurrence probability/hazard relation) is used. In which for X-Y axes, rating indexes m/t are orthogonally designated. Furthermore, division of risk category A,B,C,D are made as risk matrix and used for risk management/control. The shape of this block domain highly depends on nature law (probability density function, k=1).



Risk Diagram (Occurrence probabity-Disaster damage)

Risk category

Category	Hazards	Risk management and control
A	Earthquake	1) large damage*frequent occurrence probability 2) high priority of risk controls against severe damage
B	Fire	1) large damage*rare occurrence probability 2)next priority of risk controls by risk transfer or risk built-in
C	Traffic	1) small damage*frequent occurrence probability 2) daily matters which often occerred without control
D	Work	1) small damage*rare occurrence probability 2) risk built-in with maintenance free

Risk matrix(Risk frame)

Fig-6 Risk management: Risk diagram, risk category, risk matrix

1) Risk is defined as disaster damage (X) times its occurrence probability(Y) based upon the Pareto distribution curves of probability density function. The shape parameter k characterizes shape/concentration and cause/effects of the system.

2) Pareto distribution bases on nature law and **Table-9** is available in many fields of human activity (population), economy (wealth, inequality, globalization), and natural hazards (EQ).
3) Risk boundary (X*Y=c, k=1) implies potential energy of the system and toughness against disasters, and expresses the rating scale to the risk against hazards.
4) If risk zone is below the risk boundary, the system is safe, and if over, the system is dangerous and then should be revised and modified for safety.
5) The risk boundary is specified with codes by the authorities and public acceptance.
6) Risk diagram is classified in four categories (A, B, C, D) depending on scale of damage*occurrence(**Fig-6**). Risk control methods are as follows; a) Risk built-in(maintenance free, no care), b) Risk reduction(strengthened, protected against failures), c) Risk avoidance(original plan is rejected and eliminated), d) Risk transfer(guaranteed and covered by insurance).
7) Regional disasters and risk control; In serious cases, prevention and protection are considered. In mild cases, mitigation program is planned by reductions and distribution of the effects.

3-4 Fracture/Fatigue problems: Shear panel dampers (Fig-7, Fig-8)

Outline

It describes lens-type shear panel damper newly developed for highway bridge bearing. It utilizes low yield steel LY100 and concave lens shape panel .Both properties of low yield strength and high ductility are major requirements for damping devices. Both responses by static and dynamic tests show rectangular shape of load-displacement hysteric curves with high quality damping. Failure at the ultimate state highly depends on the cumulative deformation capacity of panel identity. Damage and life cycles can be estimated by Miner rule. Prediction matches well with the testing results. Large deformation of steel with high speed strain rate generates a lot of heat with high temperature 300~450℃.Earthquake energy is converted both to strain and heat energy, which results in large energy dissipation.

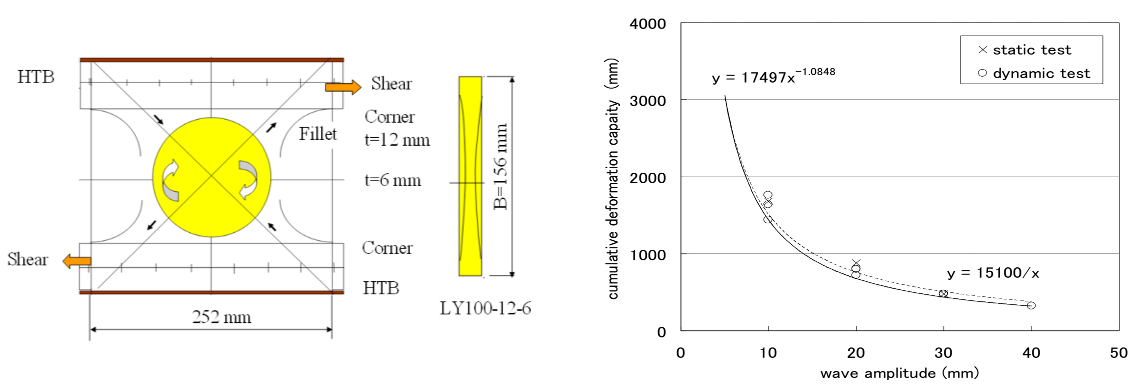
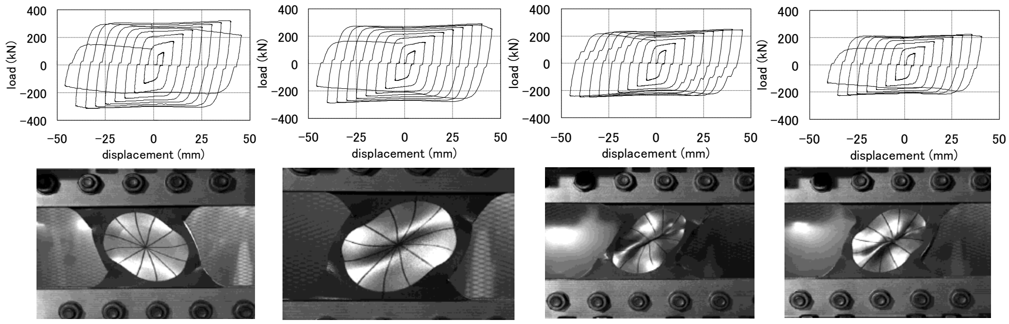


Fig-7 Lens-type shear damper:Cumulative displacement/wave amplitude



(a) LY100-12-8 (b) LY100-12-6 (c) LY100-12-4 (d) LY100-12-3

Fig-8 Lens behavior: Concave depth and failure modes control

Physical behavior: Miner rule(nature law),potential energy reserved theory, life time

Fig-7 draws the relationship between the cumulative deformation capacity (y) and the loading wave amplitude (x).

$$y = 17497\,x^{-1.0848} \quad (1)$$

$$xy = 15100 \quad (2)$$

Equation (1) is derived from the test data by the minimum square-root method. Equation (2) is the corresponding simplified formula of lens identity which means that the strain energy capacity is reserved in constant. Based upon **Miner rule**, survival number of cycles(life time) Nf and damage index Df are determined as follow.

$$N_f = 15100 / 4x^2 \quad (3)$$

$$D_f = 1 / N_f \quad (4)$$

Miner rule indicates that the design criterion to failure is defined as follow.

$$\sum (1/N_f) < 1 \quad (5)$$

Performance evaluation

The testing result matches well with Miners rule of nature law , potential energy reserved theory(XY=constant) and life time. The design of lens (shape/low yield steel) damper is reasonable enough to optimize the shape(circle/lens focus) and selection of low yield steel .The physical behavior corresponds to k=1 of Pareto distribution(**Table-9** ,stable/natural).In **Fig-6**,if the design aims to risk category B or C, too active status(k>1,top heavy) or reserved status(k<1,long tail), the damper system is required to revise the lens shape and material(strength/ductility).The lens damper **(Fig-7)** is considered to be function integrated system as expressed by V(t,x,m,h,q) due to nature law. Its multifarious evaluations from different view points (t,x,m,h,q) are totally good to be high grade/potentiality(simple, compact, cheap, high quality, strong life time).

3-5 PM theory: Human activity, performance/maintenance, career pass (Fig-9)

PM theory (performance function Y/maintenance function X) is discussed, which is handling the personal/professional duty performance. By the potential reserved theory (X*Y=constant, discreet phenomenon in this case), the human ability falls into four categories in the form of block matrix: 1)PM type: both good with high potential ability,2)Pm type: professional type with less management,3) pM type: management type on good standing in human relation.4)pm type: worker type. The job site is worked by specialist and managerial staff. There are personnel training and a principle of the right man in the right place there. As illustrated in **Fig-9**, there exist five potential ability lines. The quality/quantity of inside people is limited within narrow bound between U-line and L-line. By corporation with outside people, this narrow bound will be open and become wider much more.

1)E-line:XY=2e,excessive potential, too active(top heavy),director(outside).

2)U-line:XY=1.5e,upper bound of high potential in a company, director(inside).

3)A-line:XY=e(unit value), average potential in a company, manager(stable/natural).

4)L-line:XY=0.6e,lower bound potential, worker(inside), training and education required.

5)R-line:XY=0.3e,reserved potential, less active(long tail).worker(outside).

Career pass: As usual (**Fig-9)**, along the A-line, a specialist starts from Qs point then through Qc ,proceeds to Qe on the way to manager , achieving humanity in technology. Experimental and field studies are described which suggest that the consequence of leadership are ordinary result of interaction of P-oriented and M-oriented behaviours. When compared with U.S. leadership research results, PM research indicates that leadership at the lower and middle management levels may be consistently more important for subordinate performance in Japan than it is in the U.S. However, upper management level is required for being more successful and constructive.

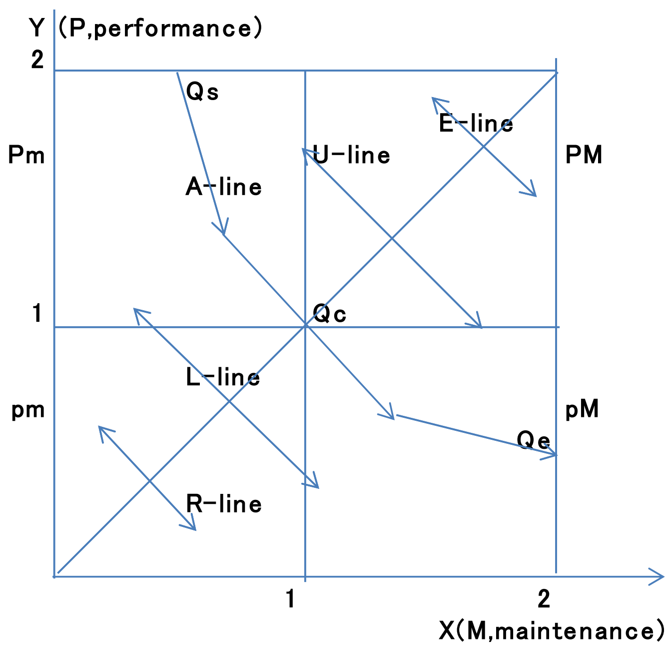


Fig-9 PM theory: Performance/maintenance, P*M=constant（potential）

CONCLUSIONS

Basic system V(F,E,I) and performance evaluation system

1) Facility(F) behaves and performs a certain interaction(I) under some environment(E). This general phenomenon (physics/chemistry) is due to nature law and also applied to general social phenomenon and human activity. The F,E,I are considered to be primary elements of basic system and each hierarch is built in detail.
2) As rating index(p),five elements are defined :time(t),space(x),humanity(h),quality(q),money(m). The performance evaluation system is formulated by mathematical model(partial differentiation form) of $\delta V(F,E,I)/ \delta p$.

3) The performance evaluation system is available in many fields: a) partial cause/effect analysis, b) primary/secondary evaluation,3) multifarious evaluation.

Basic system (F,E,I) of the steel bridge and performance evaluation

1)Based upon a model of the existing bridge, the F,E,I elements of the bridge system are organized, They are closely related to the description and articles of associated specification in edit and design use.

2)The methodology of constitution and systematization of specification are newly proposed.

3)In the performance evaluation, primary evaluation(gradient/grade),secondary evaluation(acceleration/inertia/potential) and multifarious evaluation from different view points are effective all together.

4)There exist function integrated type bridge(concrete) and function separated type bridge(metal).In case of function separated type, the evaluation is dependent on sequence order ,where priority comes first what is most important now in the social requirements.

Systematic approach to engineering matters and humanity

1)Block diagram is used sometimes. It should be orthogonally designated by independent phenomenon each other. In X-Y axes, time(t),space(x), money(m),humanity(h),quality/quantity(q) are usually chosen as the rating index which are mutually exclusive and independent phenomenon each other.

2)Based on nature law, Pareto distribution and potential energy reserved theory, three problems are explained; a)Risk management/regional disasters/risk control, b)Fracture/Fatigue problems of the shear panel dampers , c) PM theory of human activity/performance and maintenance ability/ career pass from specialist to manager.

3)Nature law, Pareto distribution and the potential energy reserved theory are available in many fields such as **systematic and theoretical approach to humanity.**

4)Performance innovates better basic system. Humanity makes new technology.

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