Requirements for crisis management in flood control plans and the design of flood control facilities

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1. CONCEPT OF CRISIS MANAGEMENT

Crisis management can be defined as all of the efforts that are made to avoid the worst possible scenario that is initially assumed within a given period in specific conditions, where the available facilities involve limited resources, manpower, and equipment. The effectiveness of this type of crisis management should be evaluated on the basis of the extent to which the severity and fatal effects of a disaster have been reduced within the scenario assumed.

Of course, this applies not only to the measures taken during the development of specific critical situations, but also to preparatory measures, as well as the measures taken after such situations have already developed.

In addition, the definition applies to the management policy and guidelines for action to be taken by the personnel in charge and the people concerned (human resources), as well as disaster control projects, such as the construction of emergency facilities (capital investment).

Crisis management is generally regarded as involving the human resources elements that need to be put in place promptly in order to cope with a critical situation or an emergency. Capital investment measures, such as projects for preventing flood damage, including flood control projects and the construction of flood control facilities, therefore have a tendency not to be regarded as crisis management measures.

However, if we are able to reduce the severity and fatal effects of a disaster by constructing flood control facilities even before a critical situation arises, we can classify such measures as preparatory steps in risk management If we are able to quickly restore the local community's level of economic activity and the residents' living standards to those prior to a critical situation or an emergency by steps taken afterwards, such measures can be termed ex post facto crisis management measures.

2. ASSUMPTION OF THE WORST SCENARIO

A situation in which a disaster turns out to be the gravest possible one in terms of scale and lethality for a society, or the least desirable situation possible arises, is termed the worst scenario. This type of a scenario should be assumed without any practical affairs being taken into consideration, such as the ability to manage the situation or the scope of responsibility for it.

In general, the worst scenario is often assumed on the basis of knowledge acquired through experience and the administrative judgment of those responsible for risk management. For this reason, it is likely that those responsible are apt to make administrative judgments, taking into consideration whether a disaster can be dealt with administratively, or whether the scale or the form of the disaster belong within the scope of their own administrative responsibilities.

For example, measures for controlling flood damage from floods that do not exceed the design flood discharges have been already formulated and implemented as a project goal by the river administration within the scope of the existing flood control measures On the other hand, measures to cope with floods exceeding the design discharge, have in the past been classified as measures to be taken after the implementation of the present flood control measures is completed. From the general point of view of the river administration, it can be stated that it is impossible to implement measures to control floods exceeding the design discharge, since the current flood control project is not complete, and such measures are to be initiated either only after they are completed, or have never been studied, because their effects are not as important as the current flood control project Consequently, it has been considered that any community affected will simply have to accept any flood damage from floods that exceed the design flood discharge.

In reality, there is always a possibility, however remote it may be, that such floods may occur In addition, there is a tendency today toward increasing urbanization in protected lowland, on the assumption that flood control measures have been implemented. In addition, with the construction of continuous levees, the danger of disasters due to collapsing levees without overflow facilities has become obvious. Even in the case of levees constructed with highly sophisticated technology, there is a possibility, however remote it may be, of the levee failing without any overflow being provided beyond the requirements of such technology. Crisis management measures are therefore required to deal with the occurrence of a flood that exceeds the design flood discharge and inundations without overflow, even though such eventualities are beyond the scope of responsibility of the river administration in present circumstances

With regard to the worst scenario, we should assume specific events that may lead to the worst situation, instead of assuming a general phenomenon or only the outcome of a disaster The reason for this is that if we work backward from the outcome or the phenomenon of a disaster when formulating preventive measures, we may be faced with many potential causes that might possibly bring about the outcome or the phenomenon, and we would therefore have to deal with a large number of causes that need preventive measures to be taken, as a result, it is very difficult to formulate specific preventive measures Instead, we need to narrow the eventualities down to those that may possibly cause a severe and lethal disaster

For instance, when considering crisis management measures for flood damage, events that could possibly lead to every possible type of flood damage include those such as inundation due to a breach, inundation due to bank overtopping, and internal water inundation. This means that we are likely to conclude that all possible forms of flood control measure are required, and it is necessary to steadily promote existing flood control projects. When I reviewed this question from the crisis management point of view, I was therefore unable to identify any new point of view However, if we specifically consider inundations due to a breach, which cause more severe and fatal damage than many other events, we can take distinct measures to deal with them, and clearly formulate measures to prevent them.

The worst possible scenario is objectively assumed by those responsible for, or in charge of crisis management. We can improve measures in a systems-engineering manner if we conduct a study that uses an event tree analysis as a method for the preparatory study of crisis management Event tree analysis is an inductive method of logical analysis This method is used to show the outcome of an event clearly after a chain of events deriving from an the initial event We use this method to present clearly a scenario starting from an initial event and leading to an accident or a disaster, and we can then specifically demonstrate how the system that has been established to study various possible accidents and ensure safety either achieves or fails to achieve its objectives By repeatedly carrying out such analyses, we can determine the type of situation that needs to be assumed in the worst possible scenario

3. FORMULATION OF PREVENTIVE MEASURES

To formulate preventive measures is to select measures to be actually implemented from a range of possible measures that might be used prevent the situation assumed as the worst scenario. Feasible and realistic measures that take into account such restraints as limited time and available resources, manpower and equipment, have to be selected from among the measures that are possible, and it is necessary to evaluate and select measures on the basis of how much they can reduce the level of severity and fatal effects of the assumed worst scenario.

Measures that prevent disasters or accidents from occurring at all are the best ones, but these will be meaningless if they are not feasible within restricted and realistic conditions. Since disasters or accidents typically need to be dealt with within a limited time and under restricted conditions in terms of resources and manpower, we cannot normally expect to be able to eliminate all disasters or prevent every accident. Consequently, if an event capable of causing the worst possible situation develops, there is nothing we can do to prevent a disaster or an accident of some kind from occurring.

The objective of preventive measures taken in such a case is to reduce the severity and fatal effects of the accident or the disaster. This requires an examination of the facilities subject to damage. It is necessary to establish a ranking for facilities that should never be subjected to disasters or accidents, and facilities for which damage due to disasters or accidents must be comparatively accepted. In this regard, those responsible for administration and those in charge of the management of facilities may need give some reconsideration to their usual assumptions.

For example, in the case of measures for preventing flood damage, a comparative study will be required to classify the facilities affected by disasters or accidents in terms of their location—namely, areas of low use and areas of high use, farmland and urban areas, ordinary urban areas, and areas in which major urban functions are concentrated, in order to determine the order of priorities for disaster prevention. In the case of measures for preventing drought damage, a comparative study is required to set priorities among agriculture, industry and the water services in the supply of water.

When carrying out such a study, the matter needs to be looked at from the point of view of how to reduce the severity and fatal effects of disasters as much as possible; from the point of view of whether facilities that have been placed high on the priority list can be repaired at an early date after the disaster; and from the point of view of whether it is possible to restore facilities to their status prior to the disaster. With regard to the study of the facilities that may be subject to damage, it is necessary to carry out sociological research, and make an effort to achieve consensus on crisis management at all times.

When formulating preventive measures, we can improve measures in a systems-engineering manner by carrying out studies based on the fault tree analysis method. Fault tree analysis is a deductive method of logical analysis. In this method, we examine the design, planning, operation and management of a system, starting from an analysis of undesirable events that are likely to bring about a fatal situation or result, and then proceeding to analyze the chain of events at the previous stage that have led to such events, in order to prevent the subsystem, facilities and members relating to the chain of events from causing that chain of events at the previous stage. We can use this method to prevent the occurrence of an abnormal event with a low likelihood of occurrence but with a high level of fatality, for example. Similarly, we can use this method in an attempt to improve systems and facilities in a systems-engineering manner. This method not only applies to ordinary systems and facilities, but also is applicable to social systems and social activities.

4. CRISIS MANAGEMENT IN FLOOD CONTROL TECHNIQUES (PLANNING AND DESIGN)

This report examines the planning and design methods for flood control techniques to which river engineers give the first priority, and does not deal with human resources aspects such as inundation prediction information, flood-fighting activities, evacuation activities, and the first-aid and life-saving activities that are carried out by many organizations in collaboration.

I have selected a flood control system consisting of facilities including levees, retarding basins, reservoir systems and floodways for examination, and I will carry out a comparative study of planning and design methods based on the concept of risk management and the planning and design methods used in conventional flood control techniques in each field of the flood control plan, which determines the standard discharge of floods for which this system is designed, the function of each flood control facility within the system, and the design of flood control facilities with regard to strength, etc.

In the conventional flood control technique, the scale of floods to be handled by the flood control system, i.e. the design flood discharge or design flood, is determined in the "flood protection plan," a part of the flood control plan This is a task that belongs to the field of hydrology. Assuming a given river course as representative of flood control facilities, a "river course plan" is determined in order to design the contours of the cross-section and longitudinal section of the river course that are required to allow the safe flow of the design flood discharge set by the "flood protection plan."

Normally, the contour of the cross-section of the levee is also designed as part of the cross-section of the river course in the "river course plan." The task of determining the contours of the cross-section and longitudinal section of the river course is part of the planning and design of the flow capacity for the river course, and therefore belongs to the field of hydraulics On the other hand, the task of determining the contour of the cross-section of the levee also belongs to the field of structural theory. The former is a task belong to the field of planning, while the latter is a task belong to the field of design. The ultimate objective of these tasks is basically to determine the design flood discharge or the design flood applicable to floods to be dealt with by the flood control facility system, in order to prevent such floods from overflowing the bank

In a flood control project, the flood control facilities specified in the flood control plan and the flood control facility design are constructed in stages over quite a long period of time, or almost permanently If a flood exceeding the design flood discharge occurs during the implementation of the flood control project, the flood control plan is reviewed, the scale of the flood control plan is extended, and the flood control project is implemented according to the revised flood control plan Generally, therefore, there is no final stage at which the construction of flood control facilities is ever completed for large rivers.

I will now examine a case in which the concept of crisis management is introduced into the field of flood control engineering The first topic here the worst scenario that needs to be assumed. The types of disaster dealt with by the existing flood control technique include natural inundations in places without levees, overtopping inundations, inundations due to the levee being penetrated by overflow, inundations due to a collapsed levee without overflow, and inland inundations A review of the data that have been gathered regarding the status of progress in flood control projects in our country and the population and assets in river basins shows that the rivers in which there is a potential for severe flood damage are large rivers running through cities

Among the different types of flood disaster mentioned above, inundations due to broken levees are the ones most likely to cause devastating damage in these rivers. For a crisis management analysis, it is therefore appropriate to assume an inundation caused by a broken levee on any of the large rivers running through cities. In the case of overtopping inundation, most of the flood flows along the river course if there is no levee, and the flood discharge can therefore be limited. In addition, the energy of natural inundations in places without levees and inland inundations is so small that even if some facilities are flooded, devastating damage is not caused by the energy of the flowing water. and the severity and fatal effects of the flood damage can be kept at a low level because of the low flood discharge

The second topic is the formulation of preventive measures Among existing flood control techniques, the "flood protection plan" and the "river course plan," including the levee design and the techniques used to prevent a breach, are the most important issues. I will review here a fault tree analysis in which a breach is placed at the top of the list of undesirable events The result is shown in Fig 1.

Of the preceding contributory events, insufficient height of the levee crest is a problem in the flood control plan, insufficient height of the levee is a problem in implementation, and other problems are related to the design of the levee. The solution of problems relating to the design of the levee is therefore the most important crisis management issue associated with large rivers running through cities.

The status of land use in Japan is not necessarily the same as that in foreign countries, and therefore what is assumed as the worst scenario may differ from country to country.

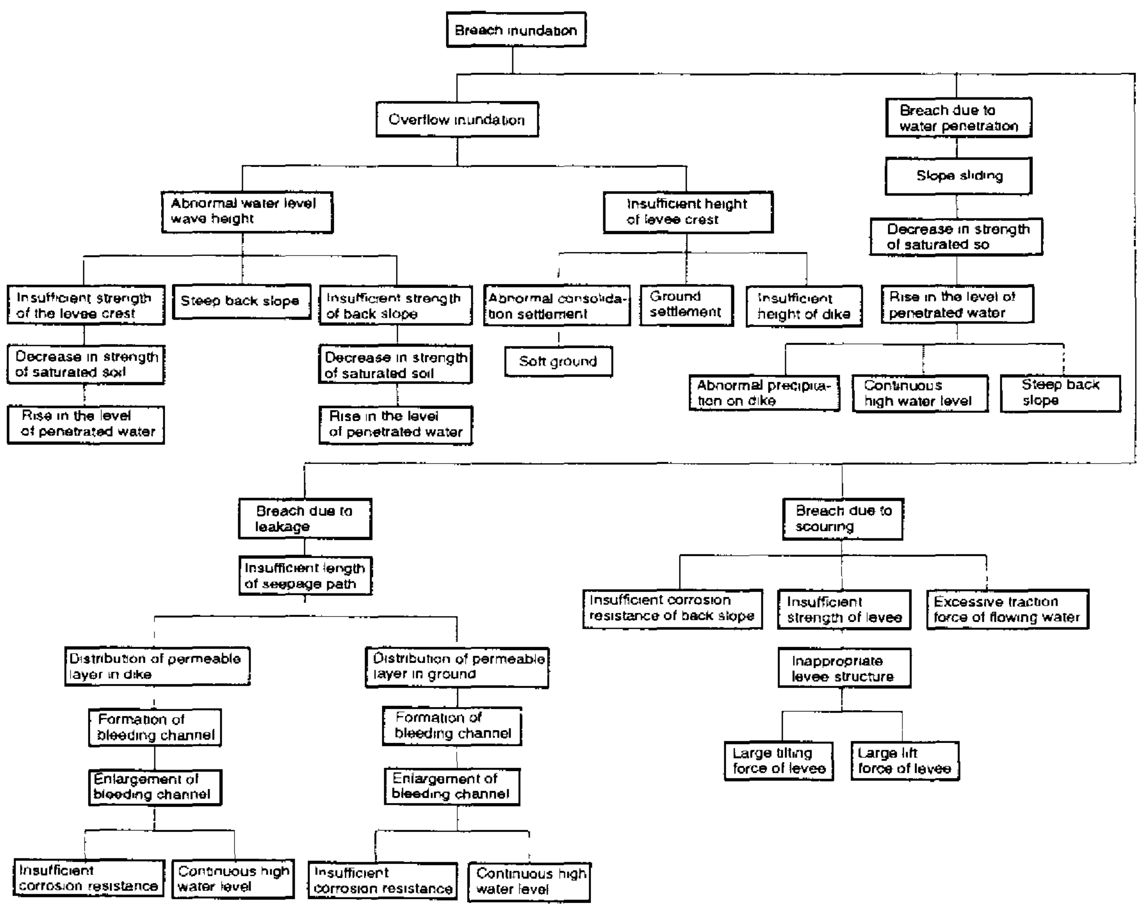

Fig. 1 Fault tree analysis of dike break

The topic of levee design belongs to the preparatory measures, and it is often thought that this is exactly the same as the existing flood control technique. Flood-fighting activities, evacuation activities, first-aid and life-saving activities are generally considered as measures for dealing with the worst scenario once it is in progress. Even in this case, the activities required during the worst scenario while it is in progress can be limited to a great extent unless the inundation is caused by a breach, and relatively small-scale crisis management will serve the purpose A study of levee design, even if it means studying preparatory measures, is therefore a very important part of crisis management. Since the restoration of a location that has been hit by a disaster, the reconstruction of the victims' living conditions and the recovery of economic activity in the stricken area can be easily achieved in the case of a small-scale flood, the design of the levee is therefore still important, even from the point of view of ex post facto measures.

5. TOPICS IN THE DESIGN OF FLOOD CONTROL FACILITIES (LEVEES)

In the preceding chapter, I examined the levee as a typical example of flood control facilities, and it became clear that the design of levees is an important task in risk management. I will therefore go on now to examine the topics involved in the design of levees in each breakage mode.

1. MEASURES TO CONTROL OVERFLOW

The main cause of the overflow breakage mechanism is the corrosive action of overflowing water at the crest of the levee and on the surface of the back slope.

This is basically caused by insufficient height of the levee, and can therefore be prevented by completing the levee to the reference cross-section (planned reference cross-section), and raising the insufficient height of the levee resulting from ground settlement and abnormal consolidation settlement Measures are required to prevent corrosion by overflowing water from causing a breach particularly in the case of an incomplete levee in an area in which the hinterland has been urbanized; in circumstances in which the levee has had to be left unattended without completion due to budgetary restraints, land acquisition and technical restraints (e g., balance between the left bank and the right bank, between the upper stream and the lower stream); and in the case of a levee that has been completed in an area in which the hinterland is likely to suffer devastating damage from a flood exceeding the design flood discharge or an abnormal flood

In this case, measures can be taken such as adding a gentle gradient to the back slope in order to limit the flow rate to such an extent that overflowing water does not cause corrosion, or constructing an anti-corrosive structure such as a levee capable of resisting the corrosive action of overflowing water on the back slope

2. MEASURES TO PREVENT WATER PENETRATION

The mechanism of breach due to water penetration works as follows: when rain falls within the levee and the river water penetrates into it, causing the levee soil to change from an unsaturated state to a saturated state, the strength of the levee is reduced, resulting in a sliding failure

The objective of measures for preventing water penetration is therefore to prevent both rainwater and river water from seeping into the levee as much as possible, and to lower the level of the groundwater as much as possible. The essential measures for preventing water penetration include 1) constructing an impervious structure in order to prevent river water or rainwater from seeping into the levee from the front slope and the upper side of the levee (including the crest and the back slope), and 2) providing a drainage facility near the toe of the back slope in order to prevent rainwater and the river water that does enter the levee from raising the level of the groundwater and facilitating the piping phenomenon, i e. letting the soil particles forming the levee run off

The provision of a drainage facility as a measure for preventing drawdown is particularly important, since river water can be prevented from entering the levee from the front slope and rainwater can be prevented from entering it from the upper side of the levee, but it is not possible to prevent water from entering the levee from the foundation

3. MEASURES FOR PREVENTING LEAKAGE

The mechanism of breach due to leakage works as follows river water and rainwater that have seeped into the levee from the front slope, the upper side of the levee and the foundation allow the soil particles forming the levee to run off, and this so-called "piping phenomenon" results in a bleeding channel, which expands, leading ultimately to breach.

As in the case of the penetration phenomenon, therefore. the objective of measures for preventing leakage is to prevent rainwater and river water from entering the levee as much as possible, and to lower the level of the water that has penetrated inside the levee as much as possible It is also important to make the hydraulic gradient of the groundwater level as gentle as possible

4. MEASURES FOR PREVENTING SCOURING

Scouring is a phenomenon in which the soil particles of the banks and the front slope are corroded by the energy of the flowing water. and the corroded surface expands, causing the levee to break It is therefore important to protect the slope of the levee from the action of the flowing water, and most of the revetment structures that have been constructed in the past were provided for this purpose. The design concept needs to be clarified further. and more practical levee structures must be designed and constructed.

Generalizing the above points, it can be concluded that it is appropriate to provide a design objective for each of the levee structures that have been built in the past without a specific design concept, and to design levees as composite structures consisting of soil and revetment. We can summarize the design concept for levee reinforcement facilities, such as revetments, as follows

1 Impervious facilities: Facilities provided in order to prevent river water and rainwater from seeping into the levee from the front slope of the levee and the upper side of the levee, and including impervious sheets and impervious cores
2 Drainage facilities: Facilities provided at the toe of the levee slope to lower the water level inside the levee It is important to provide facilities that allow water to flow in order to prevent a bleeding channel from being formed by soil particles inside the levee when they run off. and to prevent the bleeding channel from expanding and carrying soil particles away. Such facilities include filtering layers, consisting of layers for each grain size and permeable films
3. Facilities for preventing scouring: Facilities provided to prevent the energy of flowing water from corroding the soil particles on the levee surface. Revetment facilities constructed in the past have served this purpose, and it is necessary to design such facilities in such a way that they are sufficiently stable with regard to the lifting force generated by flowing water. tilting due to drag forces. sliding and suction

A combination of the above facilities makes it possible to provide a design that will reduce the uncertainty and unsteadiness of the soil levee It is assumed that a method of designing composite-type levees in which facilities with these functions are used in combination will make it possible to design reinforcement facilities in which the scale of various external forces, which have always been difficult to quantify. can in principle be represented by numerical values (targeted values). so that the levees designed in this manner do not collapse even under the worst possible conditions. As an example of a levee designed in this manner, Table 1 shows a simplified diagram of the design of levee reinforcement measures used when restoration and improvement works were designed for the Kogai River, which suffered from a disaster in August 1986

The author has been studying this method of designing a levee reinforcement system for some time from the point of view of systems engineering, in order to improve the reliability of levees and the safety of the system by reducing the uncertainty and unsteadiness of the soil by replacing its components.

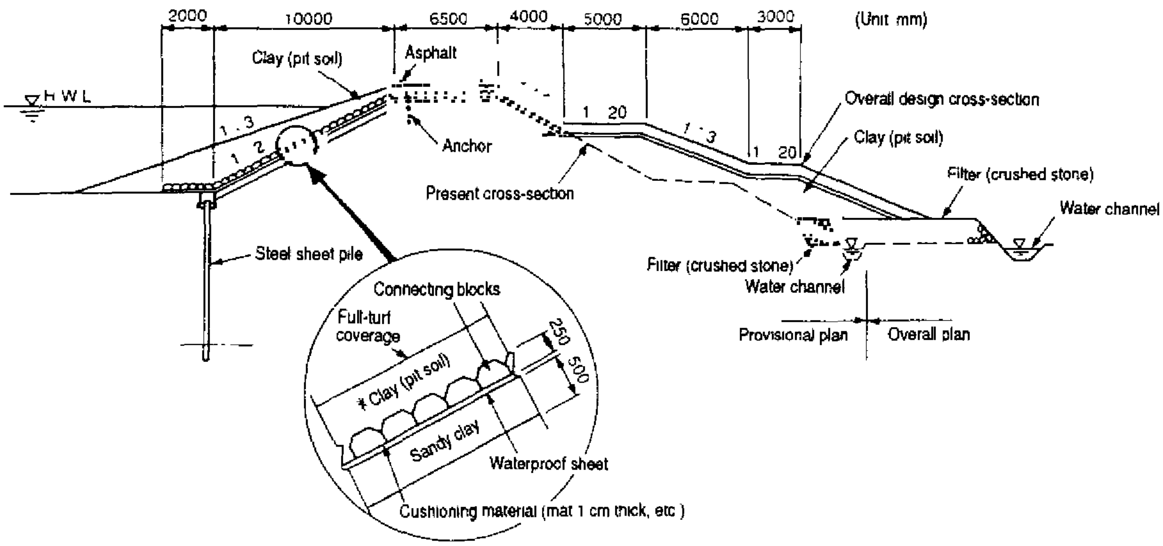

Fig. 2 Diagram of a reference cross-section of the Kogai River levee reinforcement method

Table 1 Levee reinforcement method and functions

Name	Standard	Objective	Design
1) Steel sheet pile	Standard type II	Used to prevent water from leaking from the ground into the levee and prevent scouring at the top of the levee slope	In order to isolate the permeable layer of the levee foundation, a steel sheet pile is inserted about 1 meter into the lower impervious layer
2) Capping concrete	50 cm x 50 cm	Used to integrate the impervious sheet and the steel sheet pipe in order to prevent flowing water from seeping into the levee	The impervious sheet contacts the capping concrete at the top and front of capping the concrete
3) Replacement soil	Sandy clay (50 cm thick)	Used to provide an impervious layer	Used in the section in which the entire levee is made of sandy clay
4) Impervious sheet	Flexible vinyl chloride (1 mm thick, 2 0 m wide)	Used to provide a fail-safe impervious layer, since the impervious layer formed by soil lacks uniformity	Film type is used for the impervious sheet to drain water that has entered the levee (minimum film width: 10 cm)
5) Cushioning material	Material for preventing suction (1 cm thick)	Used to prevent damage to the impervious sheet	Cushioning material integrated with the impervious sheet must be used to prevent both damage and distortion of the impervious sheet during work
6) Connecting blocks		Used to protect the levee from the scouring action of flowing water in case the topsoil runs off	Water colliding 308 kg Non-water colliding 255kg
7) Topsoil		Used to prevent deterioration of the impervious sheet, and to protect the levee from the scouring action of flowing water together with the connecting blocks.	A 3-in-1 gradient is given to provide stability in relation to sliding at the area in which the impervious sheet contacts the soil, and to stabilize the topsoil during a flood.
8) Sodding	Japanese lawn grass	Used to protect the levee from the action of flowing water	Full sodding

This method has the following features:

1. Impervious facilities and facilities for preventing scouring are provided separately.
2. The block revetment of the facility for preventing scouring is laid along the front slope and the foundation, so that it can trace any displacement of the foundation if it occurs. Many of the traditional block revetments in facilities provided to prevent scouring have structures in which the block revetments are placed on the foundation for support.
3. Connecting blocks are used for the block revetment, so that the block revetment can trace the displacement of the levee or the foundation ground. The traditional concrete block pitching and concrete grating crib works are unable to trace such displacement.
4. The block has a shape with large projections instead of a plane shape, which produces a large lifting force.
5. The topsoil is placed on the connecting blocks to improve the safety of the connecting blocks and the scouring prevention elements. The scouring prevention effect of the connecting blocks is only seen during a flood when the topsoil runs off, and it results in a significant improvement in safety.
6. The overall safety of the facilities can be improved because connecting blocks can be laid on top of the existing connecting blocks when restoration work for facilities damaged by a disaster are implemented in the future. In the current method of carrying out repairs when facilities are damaged by a disaster, the damaged facilities and adjoining facilities are removed, and they are restored to the original state. Assuming that the original facilities had 10 functions, and seven were lost due to a disaster, so that the remaining facilities had three functions left. In the present restoration method for facilities damaged by a disaster, the remaining facilities with three functions are removed, and facilities with 10 functions are built to restore the original state of the facilities.

   With this method, by contrast, the remaining facilities with three functions are preserved, and facilities with 10 functions are newly added; as a result, facilities with a total of 13 ((10 - 7) + 10=13) functions are provided. If these facilities are damaged again by a further disaster, and repair work is carried out, they may end up with a total of 16 functions ((13 - 7) + 10 = 16). If this procedure is repeated over a long period of time, we can expect to have structures with an extremely high total level of systematic safety.
7. During repair and improvement works, a mechanically stabilized filtering layer and a drainage facility are provided near the toe of the back slope. The levee is therefore constructed in such a way that the water level inside the levee will not rise. This construction prevents a rise in the level of penetrating water, and thus prevents the levee from being broken by penetrating water or leakage.
8. With regard to the topsoil, a slope gradient of 1:3 is provided after a calculation for the stabilization of the slope has been made, in order to prevent residual water pressure from causing a sliding failure.
9. In this case, since this is not a newly built levee, the method of completely removing the existing levee and constructing a new one, the safety of which is fully assured, cannot be implemented realistically. When repair and improvement work is carried out on facilities damaged by a disaster on the basis of reinforcing existing levees, the most practical and effective engineering method involves evaluating the weak points of the existing levees—which are soil levees in systems engineering terms—and correctly designing levee reinforcement facilities such as revetments.

In the theory of systems safety, the terms "serial system" and "parallel system" are used. In the serial system, elements are arranged in such a way that the collapse of one element directly leads to the collapse of the entire system. Thus, the collapse of the system is determined by the probability of failure of the weakest element in the system. By contrast, the parallel system is one in which each element functions independently, so that one broken element will not directly result in the collapse of the entire system. A parallel system has to be adopted as far as possible when the safety of a system or a structure needs to be ensured in its design.

This design concept for levee reinforcement is therefore used to enhance the systems-engineering safety of levees, by arranging the facilities in such a way that the system is a parallel one as far as possible. This is achieved by providing an impervious facility, a facility for preventing scouring, and a drainage facility as independent structures; by allowing displacement for ??? concrete and concrete block pitching as the foundation; and by providing a dual structure in which concrete blocks and topsoil are placed on top as a way of preventing scouring.

In my view, this design for levees is a substantial revision of the traditional design concept, and should be evaluated as such. In the future, I intend to design reinforcement facilities to suit breach modes such as this, and to study ways of ensuring the reliability and safety of each facility. It is time for the simple levee cross-section enlargement method to be reexamined empirically, in order to improve the reliability of flood protection structures.

The cross-section enlargement method for homogeneous soil levees leads to weak spots, since the internal inconsistencies involved increase due to the properties of soil as a material when the scale expands. It is important to establish a method of designing composite levees in which several kinds of materials and facilities that are highly resistant to the mechanisms of a variety of disasters are used in combination, in order to improve the reliability of levee structures. Of course, empirical evaluations and a stochastic analysis method are important in improving the reliability and safety of the system; however, it is perfectly reasonable to take advantage of safety engineering methods.

6. FLOOD CONTROL ENGINEERING: FROM THE PRINCIPLE OF PREVENTING INUNDATION TO THE PRINCIPLE OF MINIMIZING DAMAGE

In the research and development field, there is a method in which a traditional definition is replaced with a broader and more general one. This zigzag way of ascending toward more general concepts can be termed the switchback method; it is like a train that continues along the same rails, but is constantly climbing further up a hill. We achieve a wider range of vision and a broader view of the world each time the train passes a switchback

When we look back at the history of flood control engineering from this point of view, there are many lessons that can be learned Our country has done its utmost to implement flood control projects, making full use of the flood control techniques available in each period under poor natural and social conditions. The country's flood control techniques have developed in response to society's demands in each period.

Plains, which are both residential locations and the areas in which rivers overflow, were once developed mainly for rice cultivation In the days of rice cultivation, paddy fields were operated on low-lying land in anticipation of the benefit from rivers providing them with water for farming In those days, it was always necessary to make arrangements to allow the flowing water of a river to flow into the protected lowlands serving as farmland.

On the other hand, people had to fight the raging floods that inevitably affect lowland areas It then became necessary to make arrangements to prevent the flowing water of a river from entering protected lowland areas at all. Communities in river basins made every effort to meet two contradictory requirements: the demand for water for agricultural use during drought periods and the need to prevent inundations during flooding Flood-fighting efforts and sheds built on levees for evacuation during floods are examples of these efforts.

However, it was difficult to meet these requirements fully in practice Consequently, people living in the river basins had no choice but to endure damage from floods and inundation as their fate, as long as they had the