Avestia Publishing
International Journal of Civil Infrastructure (IJCI)
Volume 8, Year 2025
ISSN: 2563-8084
DOI: 10.11159/ijci.2025.005

Enhancing Design Standard of Agricultural Dam to Reduce Flood Risk

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Abstract *- The Agricultural Production Infrastructure Design Standard has not been revised for more than 10 years, except the Drainage Part (2012), so it needs to be upgraded to respond to changes in the agricultural environment, such as climate change and agricultural system conversion. In many countries such as the United States, Europe, and Japan, standardized codes have been established for the maintenance of agricultural infrastructure. These codes reflect the latest research and technological trends, and they are updated regularly to ensure efficient operation and management. The need for the revision of agricultural infrastructure design standards is necessary to reflect the latest technologies for responding to agricultural disasters (disasters caused by climate change such as droughts and floods), and to strengthen the standards for reducing flood risk. This study aims to revise the overall contents of the design standards for agricultural dams such as climate change response to reduce flood risk, economic feasibility analysis, and new technology introduction, incorporating the deliberations of the Central Construction Deliberation Committee, the construction standards for emergency discharge facilities, smart management, the Huff method, and the AHP method for the economic analysis.*

Keywords: agricultural dam, climate change, design standard, flood risk, emergency discharge facilities

1. Introduction

Developed countries such as the United States, Europe, and Japan have a standardized code system in the field of agricultural production infrastructure improvement, which has been established and revised to ensure efficient operation and management of the design standards by reflecting recent research and technological trends.

In the general construction field in Korea, research has been carried out to introduce a standard code system for the construction standards since 2012. The Notification No. 2013-640 of the Ministry of Land, Infrastructure and Transport "Construction Standard Code System" has been announced to introduce a standard code system for systematic management and implementation of the design standards and pursuit of the substantiality of overseas construction contracts [1]. Since 2016, standardization of the national construction standards has been carried out.

At that time, the agricultural production infrastructure field in Korea mostly used the design standards established prior to the 2000s. As the latest technological trends were not reflected, it was difficult to operate and manage the design standards and they also failed to meet international standards. Therefore, it was necessary to secure the reliability of the national design standards by revising the agricultural production infrastructure design standards managed by the government to fit the reality and providing them to the public.

Date Received: 2024-11-15
Date Revised: 2025-01-20
Date Accepted: 2025-03-10
Date Published: 2025-05-09

Recently, new design standards related to farmland commoditization, upland improvement, and reclaimed land creation are needed to overhaul the agricultural production infrastructure focusing on rice because of shifts in demand for crops, changes in the agricultural environment such as FTA, rise in rice self-sufficiency rate, and changes in dietary life. The need to strengthen the current design standards due to climate change such as increase in localized heavy rains was recognized. So, it is necessary to revise the agricultural production infrastructure design standards, a part of the Korean Design Standards. In addition, it needs to reflect related technologies so that they can conform to latest industrial trends appearing worldwide.

This study is a research on public infrastructure and aims to reflect latest technologies for responding to agricultural disasters (disasters caused by climate change, such as droughts and floods), revise the outdated national construction standards which have not been revised for a long time and develop an operation system. The final goal of this study is to derive amendments for the Agricultural Dam (KDS 67 10 00) section of the agricultural production infrastructure design standards of the agricultural production infrastructure improvement project by reflecting the latest technologies of agricultural disaster response for expansion of flood control capacity.

2. Standard Code System of the Korean Construction Standard

In terms of the management and operation of construction standards by the Ministry of Land, Infrastructure and Transport, the Korean Construction Standards consist of 51 types of the construction standards (21 types of the design standards and 30 types of the construction specifications). Tasks related to the enactment and revision of the construction standards by section have been distributed to and managed by a total of 23 related organizations, such as academic institutions and associations. So, it is difficult to reflect new technologies or construction methods in a timely manner as revision cycle is more than 5 to 6 years on average and operational efficiency is reduced because of partition-focused management of academic societies or associations when establishing and revising the construction standards. In addition, absence of a unified system resulted in duplicated or conflicting contents in the standards. It is difficult to secure accountability and unity due to lack of the revision history management of the construction standards.

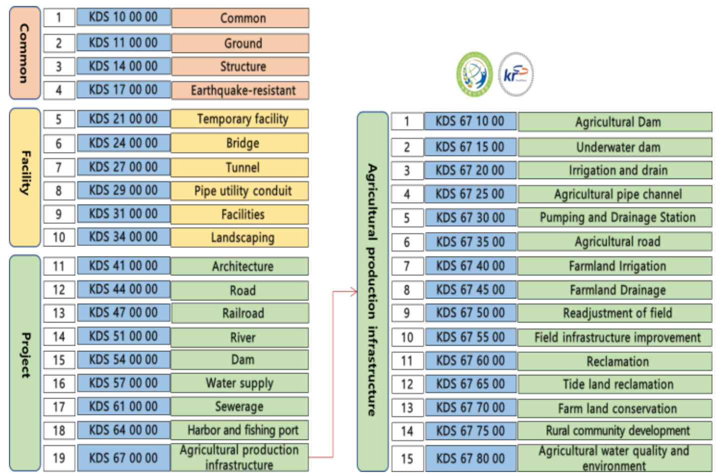

Figure 1. Status of the Korean Construction Design Standard Code System

To solve these problems, establishment of a standard code system was promoted to covert the existing construction standards set by department into a standardized numbering system, assign titles and identification numbers to each construction standard to remove duplicated or conflicting contents and enable establishing and revising the construction standards in a timely manner by allowing composition and contents of unified construction standards to be included. The Notification No. 2013-640 of the Ministry of Land, Infrastructure and Transport on October 31, 2013, the "Korean Construction Standards Code System" promoted to introduce a standard code system for systematic management of the design standards and the construction specifications and pursuit of the substantiality of overseas construction contracts [1]. In 2014, based on the newly introduced construction code system, overlapping or conflicting contents in the design standards and construction specifications were reviewed. In 2016, 34 types of the Korean Construction Standards of the Ministry of Land, Infrastructure and Transport were enacted & notified, and the "Korean Construction Standards Code Creation Guidelines" was distributed [1, 2].

For efficient management of the design standards, the existing management system has been improved. An expert committee for review and consultation was newly established in the Construction Standards Committee of the Central Construction Technology Deliberation Committee. The committee oversees the management of the Korean Construction Standards and the Korean

Design Standards. The Korea Construction Standards Centre was established to carry out tasks such as development, testing, evaluation, and promotion of construction standards. The Korea Construction Standards Centre developed a code system for the Korean Construction Standards by analysing the status and problems of domestic and foreign construction standards code systems and set strategies for establishing a construction standard management system for efficient management. According to Article 44 of the "Construction Technology Promotion Act" and Article 65 of the Enforcement Decree, it is stipulated to obtain approval from the Minister of Land, Infrastructure and Transport after getting deliberations of the Central Construction Technology Deliberation Committee when enacting, revising or abolishing construction standards, regarding the deliberation functions of the construction standards [3, 4].

As shown in Figure 1, the Korean Construction Design Standards are classified into 3 sections: Common, Facility, and Project, and the standard code for the agricultural production infrastructure design standards is largely classified as KDS 67, which includes the Agricultural Dam section [5, 6].

In 2018, the agricultural production infrastructure design standards were standardized and re-enacted. In 2019, the contents of the enactment and revision of relevant regulations such as the common earthquake-resistant design standards, and the details on actualization of earthquake-resistant design methods were added to the Agricultural Dam section.

3. Revision Directions of the Agricultural Dam Design Standards

There is a need to reflect latest technologies to respond to recent agricultural environmental changes and agricultural disasters (disasters caused by climate change, such as droughts and floods), and revise the agricultural production infrastructure design standards, which are outdated national construction standards that were enacted and revised long time ago.

Table 1. Revision Points and Directions of the Agricultural Dam Design Standards

Classification	Details
Revision points and directions of the agricultural dam design standards	Reflection of latest technological trends, laws, criteria, technologies, etc.
	Description of the overall contents of the agricultural dam design standards, incorporating realistic terms and contents
	Reflection of relevant standards in consideration of climate change
	Reflection of the results of on-site survey (demand survey on revision of the agricultural dam design standards)
	Revision of the design standards, considering designer's discretion (providing minimal impairment regulations, etc.)
	Reflection of economic analysis results of agricultural production infrastructures
	Unification of conflicting terms
	Unification of formulas and units (correcting and clearly defining formulas and units in accordance with SI units)
	Deletion of Sino-Korean words (removing Sino-Korean words and rearranging terms)

The history of the enactment and revision of the existing agricultural production infrastructure design standards is as follows. The design standards for agricultural dams were enacted in 1968, divided into the Fill Dam section and the Concrete Dam section in 1989 and last revised in 2002. In 2018, the Fill Dam section and the Concrete Dam section were integrated and re-enacted as the Agricultural Dam section. Although a revision was made to the Earthquake-Resistant part in 2019, no revisions have been made in other parts for about 20 years. Therefore, it needs to revise the design standards to keep up to date with the realistic descriptions and contents. This study aims to revise the overall contents of the agricultural dam design standards in accordance with the design standards of the Korea Construction Standards Centre, such as climate change response, economic feasibility actualization, and new technology introduction.

In addition, this study includes the contents reflecting the results of on-site demand survey to revise the design standards for agricultural dams.

This study set main revision directions of the agricultural dam design standards: firstly, reflection of latest technological trends, laws, regulations, standards, and technologies; secondly, reflection of relevant standards considering climate change; and thirdly, reflection of the results of on-site survey to the revision contents as shown in Table 1 [7, 8].

In addition, the focus of the revision of the agricultural dam design standards of the Agricultural Production Infrastructure Design Standards was on supplementation according to the requests from the deliberation process of the Central Construction

Technology Centre Deliberation Committee at the time of re-enactment in 2018 and reflection of the results of demand survey targeting hands-on workers who use the design standards [7, 8].

4. Major changes for reducing flood risk in the agricultural dam design standards

4. 1. Enhancing design standards for emergency discharge facilities

Among the 17,147 reservoirs in Korea, 16,525 (96.4%) have been in operation for more than 30 years, making them vulnerable to disasters such as insufficient flood control capacity. Furthermore, the maximum daily rainfall has more than doubled from 407mm in the 1970s to 870mm in the past decade, exacerbating the risk of flooding. To address the increasing flood risk caused by climate change, there is a growing need to enhance the flood control capacity of reservoirs and strengthen disaster response systems. To enhance the flood control capacity of reservoirs and improve their ability to respond to crises, it is necessary to establish new design criteria for emergency spillways and discharge facilities.

The construction design standards for emergency discharge facilities to enhance the flood control capacity were supplemented by adding the following to the Agricultural Dam section [9].

a. For details on the sluice design, refer to “KDS 54 20 15, Section 4.6 Spillway sluice”.
b. As a structure that can safely discharge the stored water of the reservoir, a regular or emergency discharge facility can be installed. They can be designed by referring to "Dam Appurtenant Hydraulic Structure KDS 54 80 10 : 2022, Section 4.3 Regular and Emergency discharge facilities".
c. To mitigate the risks associated with potential emergency scenarios that could compromise the integrity of the fill dam, pre-release facilities can be implemented to facilitate early discharge.
d. The discharge infrastructure may involve leveraging existing water intake components (intake towers and gates) of agricultural reservoirs or supplementing the system with additional emergency gates, siphons, and other rapid discharge apparatuses.

4. 2. Smart management for anomaly detection

The aging of agricultural purposed water supply facilities and recent climate change have led to frequent localized heavy rains that exceed design standards, causing repeated damage to facilities and flooding of agricultural farmland. Therefore, there is a growing need to establish new installation and operation standards for ICT-based measurement devices to enhance the flood control capacity of reservoirs and improve their ability to respond to crises.

For smart management for detecting anomalies, the design of dam observational procedure was supplemented by adding the following information to the Agricultural Dam section.

Particularly, for dams with a height of 15 m or more, smart safety management such as IT-based monitoring of anomalies is performed by installing measuring instruments, if necessary, in consideration of the longitudinal shape and the size of the dam. Maintenance of agricultural dams can be designed by referring to the Dam Maintenance section (KDS 54 99 00), and maintenance of dam facilities by referring to 5.3 Dam Facility Management. If the foundation ground is soft, consider installing measuring instruments even if the height is less than 15 m. The measuring instruments shall be installed intensively at the place where the maximum displacement and maximum stress are expected to act, considering the ground and site conditions.

4. 3. Rainfall distribution and duration

In the case of the current IDF distribution method, regardless of the duration of rainfall, it has the same temporal distribution at the beginning, so it does not reflect the actual rainfall pattern. Considering that the time to reach flood discharge in most project sites is within 1 to 2 hours, it is not appropriate to use the current 48-hour random duration of design rainfall as rainfall duration. Therefore, for considering field conditions, it is necessary to convert to the Huff rainfall distribution, which is a method of distributing rainfall with a dimensionless cumulative hyetograph through statistical analysis of temporal rainfall records. It needs to introduce the concept of critical duration that can determine drainage capacity with flood discharge calculated from the duration of a rainfall event which creates the highest peak flood discharge. In addition, in accordance with the “Flood Discharge Estimation Standard Guidelines”, the standard guidelines are being followed when estimating design flood discharge of a national or local river, so it is necessary to consider introducing them to the agricultural production infrastructure [10].

The rainfall distribution method was changed from the current IDF distribution method to the modified Huff's quartile method and the rainfall duration was changed from the current random duration of 48 hours to the critical duration.

4. 4. Expanding economic feasibility analysis

Since the current economic feasibility analysis uses the B/C method, policy aspects cannot be reflected in the preliminary feasibility study of agricultural production infrastructure. Therefore, the Analytic Hierarchy Process (AHP) method was added to reflect policy aspects in the preliminary feasibility study of agricultural production infrastructure to solve problems in economic feasibility of the project.

The AHP is a multi-criteria decision-making (MCDM) method that evaluates the feasibility of infrastructure projects by considering their economic viability(demand, benefit, cost estimation, etc.), policy implications(project-specific conditions, policy effects, special evaluations, etc.), and regional development impact(regional disparity, regional economic ripple effects, etc.).

4. 5. Supplementation of the parts approved on conditions by the CCD Committee

In 2018, at the time of standardization of the design standards, the parts approved on conditions by the Central Construction Deliberation Committee (supplementation of 51 parts of "No Content", unification of conflicting terms, unification of formulas and units in accordance with SI units, and deletion of Sino-Korean words) were supplemented.

5. Conclusion

The design standards for dams in the agricultural production infrastructure section were enacted in 1968, and standardized & re-enacted in 2018. In 2019, the details on the enactment and revision of related regulations, such as application of common earthquake-resistant design standards, and materialization of earthquake-resistant design methods were added to the Agricultural Dam section.

For a long time after the enactment, major contents were not revised, so the latest technologies were not reflected. In order to effectively respond to climate change and rapid changes in farming patterns, ecological environment, irrigation characteristics, etc., it is necessary to update related standards and survey & planning methods. The main revision directions of the agricultural dam design standards are: i) reflection of latest technological trends, laws, regulations, standards, technologies, etc., ii) reflection of relevant standards considering climate change, and iii) reflection of on-site investigation results. The contents of the revision are as follows.

a. The design standards of emergency discharge facilities were supplemented in Section 4.5.1.2 Facility design of KDS 67 10 20 : 2023 Agricultural fill dam design, referring to KDS 54 20 15, Section 4.6 Spillway sluice.
b. For smart management for detecting anomalies, the design of dam observational procedure was supplemented by incorporating IT-based smart management.
c. The rainfall distribution method was changed from the current IDF distribution method to the modified Huff's quartile method, and the rainfall duration was changed from the current random duration of 48 hours to the critical duration.
d. The AHP method was added to reflect the characteristics of agricultural production infrastructure in economic feasibility analysis
e. The parts approved on conditions by the Central Construction Deliberation Committee (supplementation of 51 parts of "No Content", redefinition of unclear terms, unification of formulas and units in accordance with SI units, and hangulization) were supplemented.

Acknowledgements

This research was supported by a grant(320047-05-1-SB010) from Agricultural Infrastructure and Disaster Prevention Technology Development Project funded by Korean Ministry of Agricultural, Food and Rural Affairs

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