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A FRAMEWORK FOR PERFORMANCE EVALUATION OF RIVER TRAINING WORKS

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ABSTRACT

This study proposes a framework for performance evaluation of river training works on more systematic and objective basis. Groynes or spurs are structures constructed transverse to the flow and extend from high bank or embankments into the river. These structures constitute the most widely used training works, particularly in Pakistan. The spurs are generally constructed in conjunction with subsidiary training works like diversion bunds and cunnettes. Huge expenditures have been incurred in the past and heavy investments are being made/proposed for implementation of the river training works. Therefore performance evaluation of these facilities is essential in order to learn from the experience and to optimize interventions.

Keeping in view the design, construction and O&M considerations in performance evaluations, the performance indicators are developed with reference to the relative significance of these parameters. The performance of training works can be analyzed using this suggested framework based on performance indicators. The paper concludes that statistical methods for performance evaluation of river training works are not well-established, the data on the performance is either not available or lacking, and the maintenance of spurs is suffering due to inadequate funding and/or sub-optimal management. The study recommends to define a minimum set of performance indicators for training works, to field test various scenarios of the performance indicators, and to institutionalize an effective monitoring system for objective evaluation of the performance of the training works.

INTRODUCTION

Pakistan's Rivers are characterized by highly active meandering channels and moving beds due to erodible nature of the river plains and large variations in the river discharges and sediment concentration. Seasonal floods are also regular feature or river flows in Pakistan. Extensive efforts have been made in the past to train the rivers and to protect the adjoining areas from river erosion and flood damages. This has mainly been done with the help of a network of embankments protected with various types of spurs. In spite of huge investments on their construction and maintenance, these measures have generally proved to be inadequate in achieving the perceived objectives, particularly in the event of major floods.

The training of highly unstable rivers of Indo-Gangetic plains has a long history and the resulting body of experience is unique. The impact assessment and the monitoring and prediction of morphological changes are, however, less well developed in Pakistan. It has to

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be appreciated that in highly unstable rivers, isolated river training interventions may only lead to partial control of the river and ultimate stability and safety will hardly be attainable. In addition, crisis provoked measures and socio-political pressures reflect on planning, design and construction of river training works.

The flood embankments alone cannot prevent the shifting tendency of the river course and possibility of the river attacking the embankments. Hence supplemental training and bank protection works are required that help in improving and stabilizing the channel regime so that river would flow in a well defined channel. After the 1973 floods, several projects were launched to construct spurs in conjunction with subsidiary works like diversion bunds and cunnettes. Since huge expenditures were incurred in the past and heavy investments are being made or proposed, hence there is an urgent need to evaluate the performance or river training works. Performance of selected spurs can be evaluated in quantitative terms using a set of performance indicators evolved as a part of this study.

RIVER TRAINING WORKS

River training, in the broader sense and application, covers all the engineering works constructed on a river to guide and confine the flow in the river channel and to control and regulate the river bed configuration. The main objectives of river training include flood control and protection, navigation, sediment control, channel stabilization, and flow guidance towards structures (e.g. bridges and barrages, etc.). The main types of river training works may include the following (CBI, 1989):

- ☐ Levees or embankments
- ☐ Bank Protection/pitching
- ☐ Guide Bank systems
- ☐ Groynes or spurs
- ☐ Pitched islands
- ☐ Flow deflectors and flow guiding works
- ☐ Grade control structures
- ☐ Cut-offs, and
- ☐ Miscellaneous methods

The planning and design considerations for river training are twofold: firstly the training works must be designed to withstand the design flow, and secondly the impacts and consequences on the river should be understand and evaluated whenever feasible. The training works therefore must be strong enough for the design velocity and they must also extend beyond the potential scour in order to safeguard against undermining. A river, as a system, is subject to changes in response to any type of training or regulation in the system. Such responses will usually occur at places where the bed is mobile or where the bank is unprotected. Any plan for river training needs to be evaluated with regard to the channel responses. Modifications in design are often necessary in arriving at the final workable plan. In modern river engineering, a very challenging task is the prediction of river channel behavior, which can be made either by physical modeling or by mathematical means.

Guide bund of a bridge or a barrage plays an important role in training the river besides giving protection to the approach road embankments. Conventional shape is shown in Fig. 1, but Irrigation Research Institute (IRI) continues to do research for evolving the most suitable geometric shapes. However the final decision about the location and geometries normally made by model studies. Groynes or spurs are structures constructed transverse to the river flow and extend from the bank into the river and constitute the most widely used training works in Pakistan. They can help to improve the river channel and protect river banks by deflecting or holding the flow depending upon the spur configuration and river approach conditions. It is desirable to test them on hydraulic models for optimizing their location, size and shape. Different shapes of spurs are given in Fig. 2.

River bends, under favorable conditions, become large loops with narrow necks. When the narrowing of the neck reaches a limit, a break-through occurs and chute channel known as natural 'cut-off' forms across the neck. This phenomenon may also occur by the natural overflows during floods. The beneficial effects of a cut-off indicate usefulness of artificial cut-off as a river training measure. As cut-offs reduce sharp bends and loops, where much flow head is lost by excessive length they would always be accompanied by supplementary training and grade control works to improve and stabilize flow characteristics. As subsidiary works, diversion dikes are used to close river sub-channels and sills are used for filling abnormal depths.

Due to varying physiographic, climatic and socio-economic conditions, flood problems largely differ from one area to another, thus necessitating the construction of different types of training structures. In alluvial plains of Punjab, the bunds and allied spurs have been primarily constructed to protect headworks and irrigation structures and to safeguard lines of communications, lands and towns. In Sind, almost continuous lines of embankments have been constructed along the Indus River without extensive provision of spurs.

PERFORMANCE EVALUATION

A simple definition of performance is "the degree of achievement of desired objective". The process of determining the quality of objectives or outputs during a monitoring program is Evaluation. Performance itself tends to be weaker if no one is going to evaluate it. The concept of performance evaluation is fundamental to the successful management of all the systems, including flood protection system. The designers, planners and decision makers must know as to what is going on to achieve the desired objectives and to what extend such aim are currently being achieved. This can only be done by means of performance evaluation. Managers should also know what their system is expected to achieve, and to what extend these aims are currently being met. When there is evidence of significant under-achievement, then managers must identify and apply performance-enhancing strategies. These performance-enhancing strategies usually have to be evolved by combination of experience, analysis, and analogy with events observed at the same or some other similar systems. Various constraints in performance evaluation of river training works are briefly described in the following paragraphs.

CONSTRAINTS IN PERFORMANCE EVALUATION OF RIVER TRAINING WORKS

Design Constraints

The design influences the performance of the flood projects in tow ways: through the formal set of technical procedures and assumptions adopted for its design and through the typical operational schedules. The adequacy of the existing data regarding river discharges, river regimes etc. can become an issue for design of training works through physical modeling. The agencies engaged for collection of this data and preparation of river plans need to be asked for detailed survey and investigations. Such data is required to be reviewed and got updated (if necessary) by agency engaged in model studies for optimal performance of the recommended design of the training works.

Construction Constraints

The quality of construction also has an impact on performance of river training works in an number of ways. A set of "as-built" drawings for the training works should be prepared immediately after construction in order to ascertain the design levels of key parts of the structures. In case the as-built drawings are not available or the deviations from the design during construction are not systematically recorded, it becomes difficult for the operating agency to recognize construction defects, and the true protection capacities of the structures. An implicit assumption that the construction is perfect, is far from true and hence may affect long-term performance of the system. In addition, work of inferior quality and inadequate pitching or aprons might endanger the safety of the training works, resulting in total or partial collapsing of the structures. Limited financial resources and complex approval mechanism also can have adverse impacts on the potential performance of the system due to cost overruns and adverse impacts on the potential performance of the system due to cost overruns and implementation delays.

Operation and Maintenance Constraints

Once the system is constructed, the quality of maintenance determines the long-term capability of the system to perform at expected levels. The decisions, on when to commence the maintenance for a season, sometimes leave inadequate time for appropriate maintenance of the system. Sometimes, the maintenance staff is either not properly organized or motivated to carry out maintenance work effectively. This leads to operational difficulties and performance inadequacies. The main constraint, however, in most cases stems from insufficient O&M funds, particularly for the routine repairs before the commencement of a food season. The lack of systematic and well established procedure for prioritizing and conducting O&M activities further inhibits performance.

PROPOSED FRAMEWORK FOR THE PERFORMANCE EVALUATION OF RIVER TRAINING WORKS

An effort is made to identify the factors which can influence the level of performance of river training works. These factors will be termed as performance indicators. Keeping in

view their relative importance and possible effects to achieve the overall objectives, a specific weightage has been proposed for each indicator, as discussed in detail in the following sections.

Performance Indicators

In order to improve a system, one must have an adequate measure of the performance of the system. Turning to the problem of measuring performance, in relation to whatever set of current objectives, the first step required is to choose a set of performance indicators. An indicator tells us the level of actual achievement, in respect of one of the objectives of the system. It may be a dimensional number, a dimensionless ratio or may be associated with some standard or target value which compares actual conditions with the planned ones.

System managers must choose performance indicators that are not too difficult or too expensive to measure on a routine basis for reasonably long time. Specifications of indicators must be clearly defined right from the beginning because changes in the definition or in the mode of computation of an indicator can invalidate analysis of time-series trends. The emphasis should be given on "defining the minimal amount of information necessary to properly estimate whether the system is performing adequately or not.

For performance evaluation of river training works, performance indicators developed are summarized in Table 1. These indicators may act as a sort of check list for performance evaluation. These include comparison of recommendations of the model studies and prototype construction, specifications, construction priority, construction cost, construction quality and apron & pitching quantities and levels. Time related performance, maintenance priority, O&M cost and benefit/cost ratio has also been identified as performance indicators in this framework for the performance evaluation of river training works. The process of identifying the performance indicators and their relative weightage proposed in this paper is based on review and collection of data of river training works, as well as extensive discussions with PID staff involved in design, model studies, construction and maintenance of river training works.

In the process of performance evaluation of river training works, the different components of spurs need to be compared with those recommended by model studies. If some deviations from the design are encountered, then those would reflect on the performance of the spurs. Similarly if the construction is not upto the mark due to multiple reasons encountered during implementation, then also the performance of these spurs would be affected.

Delayed construction also impinges on the performance of spurs. It may involve time lags amongst various activities like occurrence of problem, solution proposed by the Irrigation Division of PID and clearance by the competent authorities. In addition, time lag between river survey and the model study, and the time lag between proposals and their implementation can impact the performance of the constructed facilities due to changes in river course or other field conditions. Furthermore, the award of contract may be subject to delays in case the competing contractors go into litigation against the decision of Engineer.

There may also arise socio-economic pressure due to multiple impact of spurs on other locations leading to delayed construction, additional costs and compromise on layouts. All these factors have definite impact on the subsequent performance of the constructed facilities.

Once the spur is constructed the maintenance priority, the maintenance quality and the inflow of O&M funds would affect the time related performance in different periods particularly during catastrophic floods. Multiple reasons for poor construction or maintenance may be lack of technical supervision, lack of staff/labour co-operation, contractors' poor performance, political interferences, staff transfers, and hasty completion at the cost of quality/standards due to arrival of flood season.

Proposed Weightage of Performance Indicators (PIs)

Each performance indicator given below has been assigned a specific weightage in table 1 keeping in view their relative significance. This is basically an attempt to quantify the process of performance evaluation. This is being done on the basis of the data collected, observations made during visits of some of the prototype spurs and discussions made with PID staff. The aggregate marks obtained by each case to be evaluated would indicate the performance status of these works in quantitative terms.

According to this framework:

1. Performance of works will be treated as poor if aggregate score of the training work is less than 50%.
2. Performance status of the training works will be rated as tolerable if points scored are between 50%-70%.
3. Performance status will be considered good if aggregate score obtained are from 70% to 85%.
4. Performance status will be considered excellent if the points scored, according to this framework, are above 85%.

Description of the Performance Indicators

A. General

A1 Name of Spur, its location with respect to bank or bund or the hydraulic structure

A2 Brief description of the problem and solution proposed by the Irrigation Division of PID and initiating data.

A3 Basis of plan/design and recommending authority (Technical Committee/IRI) along with clearance dates.

A4 Economic Evaluation: Expected life of the scheme, Benefit cost ratios at various discount rates, economic internal rate of return (EIRR) and Economic Feasibility Status.

B. Performance Indicators (PIs) with respect to Design and Construction.

B1 Model and prototype comparisons lengths, shapes of spurs heads, locations, alignments with respect to thalweg, etc.

B2 Prototype specifications for top width, u/s and d/s side slopes, apron dimensions and top level indicating free board provision upon Design Highest Flood Level (DHFL).
B3 Construction priority (High/Medium/Low), starting and completion dates and time lags involved between various activities leading to delayed construction.
B4 Cost revisions from original approved cost, finally revised cost and reasons for its revisions.
B5 Construction quality of different components of spur (Excellent/Good/Tolerable/poor) and multiple reason for good construction quality.
B6 Stone pitching/apron quantities and their levels.

C. Performance Indicators (PIs) with respect to Operation and Maintenance (O&M).

C1 Time related performance during different floods, particularly catastrophic flood (Excellent/Good/Tolerable/Poor).
C2 Maintenance priority (High/Medium/Low) and Maintenance quality (Excellent/Good/Tolerable/Poor).
C3 O&M Cost Analysis: Anticipated annual O&M costs while preparing PC-I proforma and its ratios with construction cost for first five years of O&M;Actual annual O&M costs incurred and its ratios with construction cost for first five years of O&M and reasons for excessive O&M costs.
C4 Benefits perceived during Economic Evaluation of scheme while preparing PC-1 proforma and its comparisons with benefits actually achieved during O&M.

Table 1. Proposed Weightages of Performance Indicators (PIs) for Performance Evaluation of River Training works

B.	Performance Indicators (PIs) with respect to Design and Construction	Proposed Weightage in terms of performance (%)
B1	Model and Prototype Comparisons	10
B2	Prototype specifications	5
B3	Construction priority	5
B4	Construction cost revisions	5
B5	Construction quality	10
B6	Stone Pitching/Apron quantities and their levels	15
	Sub-Total	50
C	Performance Indicators (PIs) with respect to Operation and Maintenance	
C1	Time related performance	15
C2	O&M Priority and quality	5
C3	O&M Cost analysis	15
C4	Benefits: Actual Vs Perceived	15
	Sub-total	50
	Grand Total	100

CONCLUSIONS

Following conclusions can be drawn from this study:

1. In our country statistical methods for Performance Evaluation or river training works are not well established. It is worth mentioning that a lot of time and efforts are required for collection, analysis, rearranging and interpreting the data for performance evaluation. Some other agencies might have already collected the needed data for their own purpose and it often becomes difficult to sort out the needed data, examine its quality and validity for analysis.
2. It is very difficult to locate and access various kinds of records that different offices and professional organizations keep. Perhaps in certain cases the scattered informations in official files may contradict the published reports. The need for filterations/revalidation of data is thus urgent and absolutely essential.
3. During the process of analysis for performance evaluation, it is found out that no detailed data of the training works except for those constructed at barrages are kept for ready reference. The training works at barrages receive somewhat better treatment.
4. The training works are generally constructed at the locations, layout and design recommended by the model studies. In certain cases, however, where the river approach conditions are difficult and do not permit the construction at exact locations, the locations are slightly changed with the permission of the component authority.
5. The model studies recommendations are generally found effective in arresting the river erosion problems. During flood flows, subsidence of stone pitching and aprons launching are checked by stone dumping. To repair the damaged stretches, stone studs of different dimensions are constructed.
6. The maintenance of training works is badly suffering due to inadequate O&M funds. It is however observed that adequate regular maintenance staff has been posted at the Headworks but their output is sub-optimal.
7. There is an urgent need to institutionalize an effective monitoring system for objective and unbiased performance evaluation of the entire population of training works in order to learn from the experience and to optimize the future interventions.

RECOMMENDATIONS

1. The issue of performance measures involve identification/fulfillment current objectives and a set of relevant performance indicators (PIs). Managers must choose PIs that are not too difficult or too expensive to measure on a routine basis over long time. Specifications of indicators must be precise right from beginning because changes in the definition or in the mode of assessment/measurement can invalidate analysis of time series trends. Emphasis should be given on defining the minimal amount of information necessary to properly estimate whether the training works are performing satisfactorily or not.
2. It is desirable to centralize the analysis of data for performance evaluation of river training works but to decentralize its collection. What is suggested, is not involving large expenditure and staff but a slight adaptation of standard planning process for collection and analysis of data. In PIDs' planning/research organizations, adequate staff is available to carry out refined analysis. The data collection can be decentralized to the Irrigation

Division of PID and the collected data is the prescribed format should be conveyed to the Secretariat with copy to the concerned SEs/CEs. It is also desirable to start the process of data collection immediately after the project is completed because the delayed monitoring may obscure the performance assessment.

3. The analysis for performance evaluation may first be conducted over a few systems with good performance record in order to test and refine the performance indicators with a view to evolving an optimal framework for performance assessment. The performance evaluation of various projects enables the managers to determine the major sources of performance inadequacies and to address the identified constraints for optimizing the performance of future interventions.

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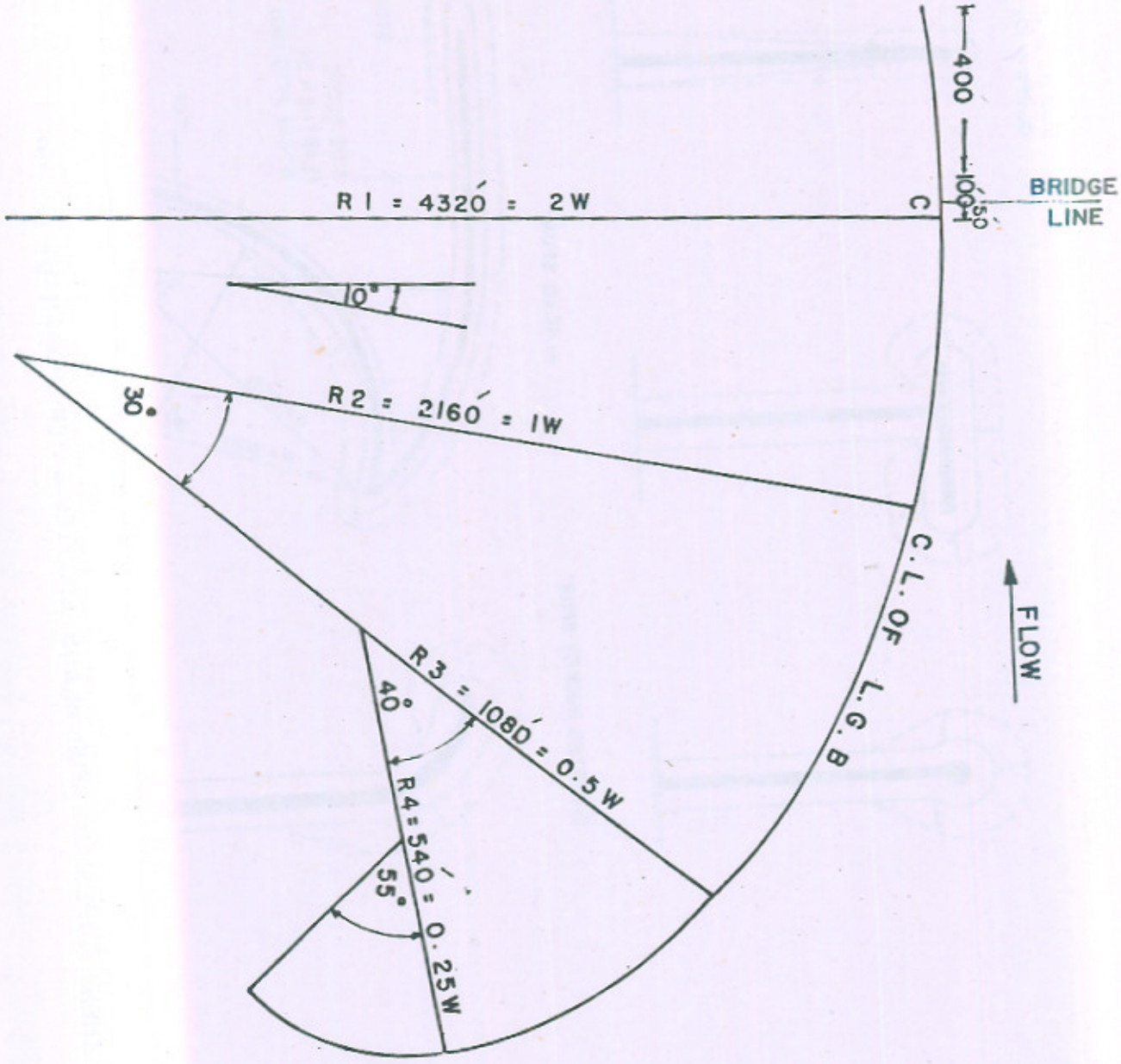


FIGURE 1: BRIDGE GUIDE BUND (COURTESY: IRI, LAHORE)

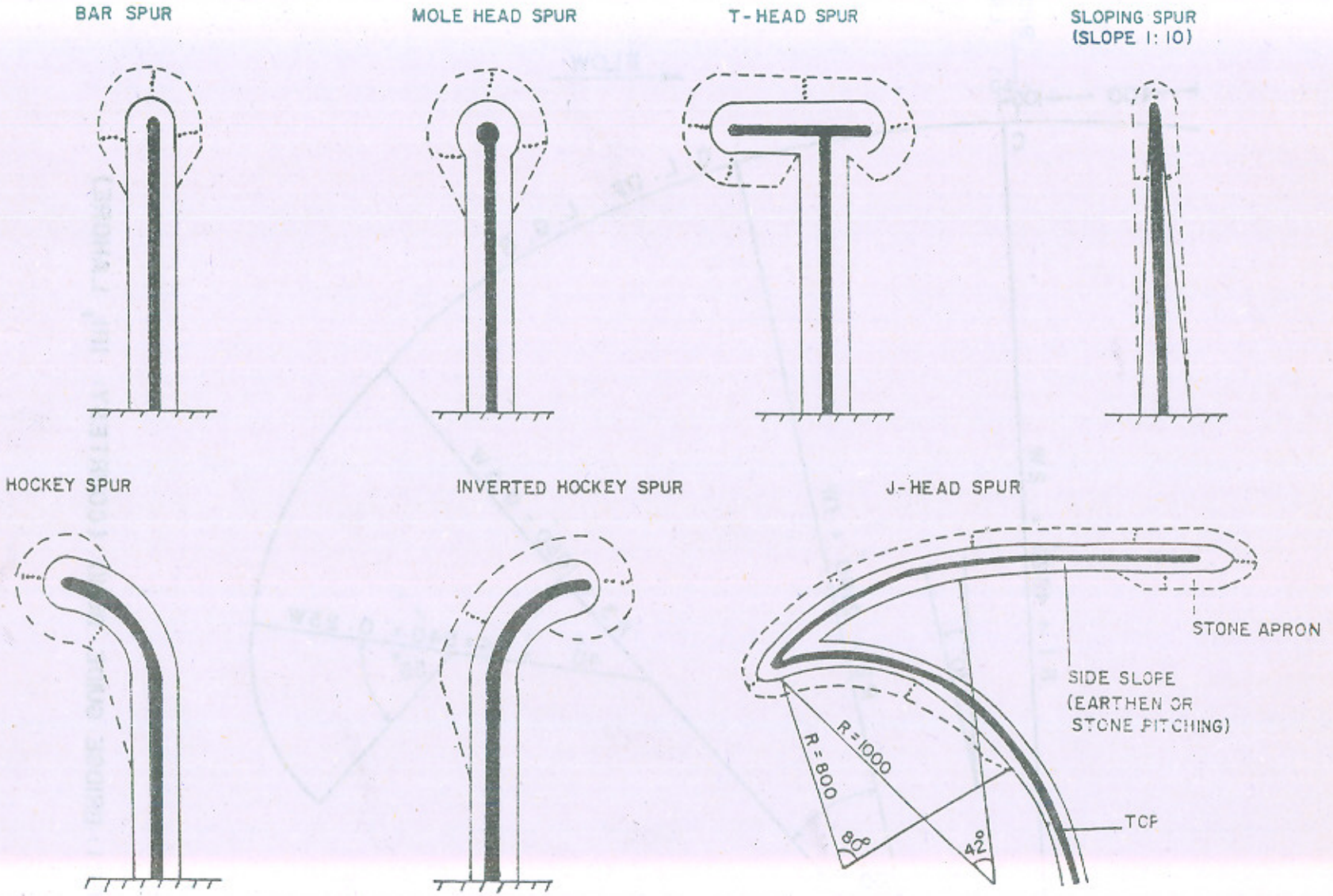


FIGURE 2 : DIFFERENT TYPES OF SPUR HEADS ADOPTED AFTER CHOHAN ET AL (1987)