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Design Analysis of a Bridge to prevail over Natural Disasters

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ABSTRACT

This paper discusses a Bridge Design to overcome all types of disasters. The author has covered all design aspects, keeping in mind design life, imposed loads, seismic force, construction material as well as IS CODES. Everything is constructed on Staad Pro, Excel sheet and designed on limit state method keeping in mind all safety points.

1. Introduction

A disaster is a sudden, calamitous event that seriously disrupts the functioning of a community or society and causes human, material, and economic or environmental losses that exceed the community's or society's ability to cope using its own resources. Researchers have been studying disasters for more than a century, and for more than forty years disaster research. The studies reflect a common opinion when they argue that all disasters can be seen as being human-made, their reasoning being that human actions before the strike of the hazard can prevent it developing into a disaster [1]. All disasters are hence the result of human failure to introduce appropriate disaster management measures. Hazards are routinely divided into natural or human-made, although complex disasters, where there is no single root cause, are more common in developing countries.

A specific disaster may spawn a secondary disaster that increases the impact. A classic example is an earthquake that causes a tsunami, resulting in coastal flooding [2]. A natural hazard is a natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage [3]. Various phenomena like earthquakes, landslides, volcanic eruptions, floods, hurricanes, tornadoes, blizzards, tsunamis, and cyclones are all natural hazards that kill thousands of people and destroy billions of dollars of habitat and property each year.

However, the rapid growth of the world's population and its increased concentration often in hazardous environments has escalated both the frequency and severity of disasters. With the tropical climate and unstable land forms, coupled with deforestation, unplanned growth proliferation, non-engineered constructions which make the disaster-prone areas more vulnerable, tardy communication, and poor or no budgetary allocation for disaster prevention, developing countries suffer more or less chronically from natural disasters. Asia tops the list of casualties caused by natural hazards [4,5]. Airplane crashes and terrorist attacks are examples of man-made disasters: they cause pollution, kill people, and damage property.

2. Role of Civil Engineering Students

Students of civil engineering need to give due importance and attention to each and every subject that forms a part of their under-graduate and post-graduate studies. The course structure and syllabus is designed to impart the necessary theoretical background of all aspects of civil engineering. However, practical training is a very important aspect of the curriculum and students should take it seriously. More site visits and interaction with professionals will enable a better concept of the construction process and will familiarize students with the latest practices. Seminars and project work in advanced and interdisciplinary areas will broaden the students' knowledge about the civil engineering field [6,7].

The involvement of students in on-site training strengthens their understanding of various construction activities. Students should learn about various types of disasters and about the behaviour of various structures during earthquakes, tsunamis and cyclones. Students should also be aware about the blast resistant features of structures. A strong theoretical background and a significant amount of practical exposure will help young engineering graduates to prevent and control the adverse effects of unforeseen disasters before they occur, and to mitigate their effects afterwards [8,9].

3. Structure Details and Reference Codes

1) Structure Details

a)	Structure Type	:-	**RCC Box Minor Bridge**
b)	Proposed Design Chainage	:-	
c)	Size	:-	3 x 6.07 x 6
d)	Box Width upto centre of Median	:-	13.79 m
e)	Earth Cushion (max)	:-	0.0 m

2) Materials Used

a)	Grade of Concrete for Box Structure	:-	M 35
b)	Grade of Steel :	:-	Fe 500

3) Codes Used :

a) IRC 6 : 2014 Code of Practice for Road bridges, Sec-II : Loads & Stresses

b) IRC 112 : 2011 Code of Practice for Concrete Road bridges

c) IRC 78 : 2014 Code for Practice for Road bridges, Sec-VI : Foundations & Substructure

4.) Modeling and Analysis considerations [10]:

- Structure is idealized as plane frame centre to centre of components, of unit width and analysed using STAAD Pro.
- Bottom slab is assumed to be supported on number of springs.
- Modulus of Subgrade Reaction has been calculated as per J. E. Bowles
- For analysis, the box model is subjected to Dead loads, SIDL, Earth pressures, Surcharge loads on the side walls, and Live Loads.
- 3 Lane vehicle loading conforming to IRC-6: 2014 is used.
- The dispersion of live load is calculated using effective slab width method as per Annexure B-3 of IRC 112-2011.

5) Design Philosophy:

Various combination of loads are adopted for checking structural strength & Serviceability Limit State

a) Ultimate Limit State (ULS):

For structural strength of various components.

b) Serviceability Limit State (SLS):

Rare combination are adopted to check the stresses in various components

Quasi-permanent Combinations adopted for checking the crack width.

6) Environment Condition Considered:

Environmental exposure condition for the structure is considered as

(as defined in Table 14.1 of IRC -112)

7) Construction Sequence Considered:

The following construction sequence has been considered in the design.

Lay the bottom slab- then side wall- then cast the Top slab.

Filling shall be done behind either end wall or abutment walls simultaneously [11].

5. Role of civil engineers

Policy makers and planners should prepare the development plan of an area considering the vulnerability of the area to various hazards. Specifications and guidelines for construction activities should be carefully laid down particularly for vulnerable areas. Before sanctioning any project, all the details need to be scrutinized by the authorities. A third party check or peer review should be insisted upon at the design and supervision stages. Local authorities must check for compliance of the project with all the requirements or specifications before granting Building Use (BU) permission [12]. Structural engineers should be involved from the planning stage of the structures and should follow all specifications laid down by the Code of Practices.

The structural engineer needs to use the latest methods of analysis and provide well-detailed structural drawings including ductile detailing. Advanced methods like Performance Based Design (PBD) must be followed for high-rise and irregular buildings rather than following simple code-based approaches. Advanced materials like High Performance Concrete, Fiber Reinforced Concrete, Self Compacting Concrete, Fiber Reinforced Polymers etc. should be used whenever required in the construction of new buildings and in the retrofitting of existing structures. Soft storey's, floating columns and other structural irregularities need to be avoided [6]. A geotechnical engineer should provide a detailed investigation of the subsoil, which would be particularly useful for earthquake-resistant design [13].

The site-specific ground response and the liquefaction potential must be assessed before the planning and execution of a project. An irrigation engineer can provide hydrological data for structures like bridges and dams that have to be constructed on rivers. A hydraulic engineer can suggest flood control measures including early warning systems [6]. The construction manager can schedule the activities on site so that there will be enough time, material and manpower to execute the job. He must also ensure quality control of each activity. The project manager can liaise between all the agencies involved in the execution of the construction project and should monitor the progress of the project. Site supervisors or site engineers execute various construction activities [9].

It is their responsibility to use appropriate material and appropriate construction technologies, and get the work done as per the detailed drawings and specifications. In particular, earthquake resistant construction practices need to be followed. If any problem occurs on site, it should be solved in consultation with the structural engineer. The materials used in construction like concrete and reinforcement (ductile steel) must be tested for quality. It is necessary to maintain documentary evidence (in the form of drawings, reports, photographs etc.) of all construction activities that are undertaken [10]. After the construction work is completed, it becomes the responsibility of the users of the buildings to ensure proper maintenance.

If any addition or alteration in the structure or building use is required, a structural engineer should be consulted. Civil engineers also play an important role in post-disaster conditions – in rescue operations, damage assessment and the retrofitting of structures [14]. Civil engineers need to keep themselves updated about the latest research and developments in construction technology, advances in construction materials and analysis or design procedures. A convenient way of achieving this goal is by attending seminars, workshops, training programmes and conferences. Civil engineers should also take support from other branches of engineering for the better planning, execution and functioning of their building and infrastructure projects.

6. Structural design analysis of concrete bridges

The purpose of a structural analysis is to evaluate the response of a structure. This can be of interest for many reasons, where the most common are design of new structures or assessment of existing ones. In design one aims towards providing a distribution of sectional forces, see Figure 1, while assessment aims towards accurately describing the response during loading and/or failure. In the current European design code for concrete structures, Eurocode 2, SS-EN 1992- 2 (2005), four examples of methods for structural analysis are presented. These are [15]:

- Linear elastic analysis
- Linear elastic analysis with limited redistribution
- Plastic analysis
- Non-linear analysis

Out of these methods it is only the non-linear which is capable of accurate prediction of the response during loading and describe the complex force redistribution taking place when cracking of concrete and yielding of reinforcement occurs, Engström (2011a). This means that it is only the non-linear analysis which accurately predicts the behavior of the structure in service state, and the mode of ultimate failure. However, the non-linear analysis requires substantial effort in establishment and post processing of the model, as well as a large computational effort. It also requires the knowledge of the complete layout of the structure beforehand, making it a method suitable for accurate assessment of existing structures but not suitable for design purposes since this knowledge is not available at a design stage. Another major drawback for non-linear modelling in a design stage of reinforced concrete bridges is that non-linear analysis does not allow for load superposition. For bridge design applications with many different loads and load combinations it is essential from a practical point of view that load superposition is possible [16].

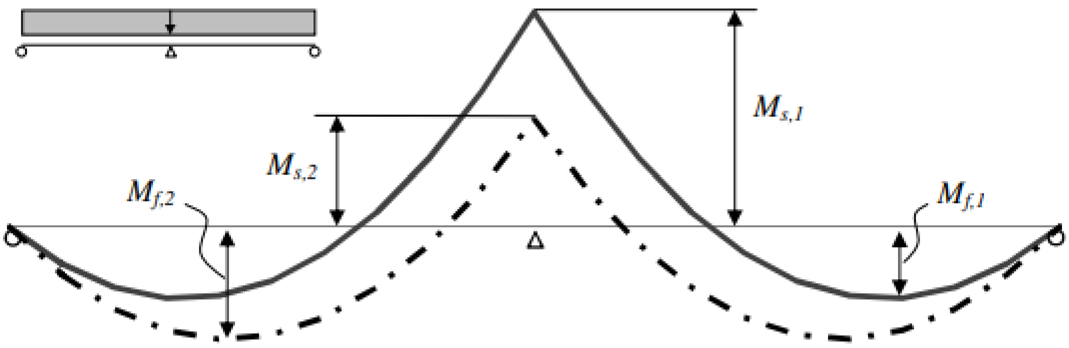

Figure 1: Possible moment distributions for design in ultimate limit state of a uniformly loaded continuous beam

When performing a structural analysis at a design stage the aim is to provide a realistic and suitable distribution of sectional forces which fulfils equilibrium and can be used for design of the cross-sections in ULS. Since most bridge structures are statically indeterminate structures, there are many distributions (in fact an infinite number) that fulfils equilibrium, though of course not all are suitable for design with regard to plastic redistribution and serviceability [17,18].

7. Conclusions

- Box for cross drainage works across high embankments has many advantages compared to slab culvert.
- Box structure is easy to add length in the event of widening of the road.
- Box is structurally very strong, rigid & safe.
- Box does not need any elaborate foundation and can easily be placed over soft foundation by increasing base slab projection to retain base pressure within safe bearing capacity of ground soil.

- Box of required size can be placed within the embankment at any elevation by varying cushion. This is not possible in case of slab culvert.
- Easy to construct, practically no maintenance, can have multicell to match discharge within smaller height of embankment.
- Small variation in co-efficient of earth pressure has little influence on the design of box particularly without cushion.
- For box structure without cushion taking effective width corresponding to α for continuous slab shall not be correct. It is likely to provide design moments and shear on lower side hence not safe.
- For box without cushion braking force is required to be considered particularly for smaller span culverts. Further, for distribution of braking force effects the same effective width as applicable for vertical application of live load shall be considered. If braking force is not considered or distributed over the whole length of box (not restricted within the effective width) shall be unsafe.
- For box without cushion having low design moments and shear stress as compared to the box having cushion. So, steel required is less in the box with no cushion as compared to with cushion.

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