SETSCI Conference Proceedings
4 (7), 181-186, 2019

4th International Symposium on Innovative Approaches in Architecture, Planning and Design

November 22-24, 2019, Samsun, Turkey

https://doi.org/10.36287/setsci.4.7.048

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The Use of New Approaches in Civil Engineering Decisions for Disaster Risk Reduction

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Paper Type: Full Paper

Abstract - Many structures, machinery, equipment, heritages, also socio-cultural systems may be subject to the unfavourable impacts, caused by various disaster risks, such as flooding, heavy snow, earthquakes, landslides, hurricanes, etc. For prevention and reduction of disaster risks, modern innovative engineering approaches should be used. In this paper, innovative decisions are received using modern entrepreneurship approaches on the macro level and innovative solutions at the micro-level. Entrepreneurship approaches mean to use the main principals of Ideation (Creativity, Detecting Problems, Sources of Ideas); Customer Discovery; Value Propositions; Business Model Canvas; Team Building; Validation, etc. systems. Innovative methods mean use of modern scientific approaches for receiving best solutions such as Pre-stressing techniques for steel and reinforced concrete structures; to consider stability problems of the rod system in the elastoplastic working region of the materials; using deploying systems in the structures; etc. The main objectives of the study were to develop such approaches that would allow increase of the load caring capacity of the structures for reducing disaster risks. New approaches to reducing disaster risks and increase of the load capacity of structures were developed through which the structural reliability was increased by almost 20% compared to the existing approaches.
Keywords – *Disaster Risk Reduction, Stability, Pre-stressed Truss, Extreme Bridges, Critical Stress*

I. INTRODUCTION

Modern society, communities, structures, economic and socio-cultural systems, heritages are exposed to various disaster risks. Reducing disaster risk is one of the priorities of UN activities. Despite UN efforts, over the past decade, as a result of disasters, the number of deaths in the world has exceeded 700,000. About 1,4 million people were injured, about 2,3 million people were left homeless, and the total economic loss amounted to 1,3 trillion dollars. Besides, in 2008-2012, 144 million people were displaced as a result of disasters [1].

Two numbers - 144 million and 2,3 million are noteworthy. Buildings are implied behind these numbers. Some of them were destroyed as a result of earthquakes, storms and other impacts. Some were built in a place where they should not be built, some were built poorly, some were built well, but the building codes were substandard. In all these cases, displaced victims complained to builders. The Sendai Framework for Disaster Risk Reduction 2015–2030 was adopted at the Third United Nations World Conference on Disaster Risk Reduction, held in 2015 in Sendai, Japan. It states that the major leverage for successful implementation of the program is the wide application of scientific and technological achievements. Also, the priority activities set by this program are necessary to reduce these risks for enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation, and reconstruction, which means the construction with better quality [2]. The main objectives of the study were to develop such approaches that would allow increasing the load caring capacity of the structures for reducing disaster risks. New approaches for reducing disaster risks and increasing the load capacity of structures were developed through which the structural reliability was increased by almost 20% compared to the existing approaches [3].

II. MATERIALS AND METHOD

Disaster Risks Problem Formulation

General aspects of understanding disaster risks and hazards. In general, the risk is a possible formation of an emergency. It is determined as negative impacts and consequences on the life, health, and property of the endangered person, as well as the environment.

Risk definition involves the entire process of risk identification, risk analysis, and risk assessment. In addition, it is a key component of risk management. Risk definition includes a comparative process of risk analysis, and results to the risk criteria. Besides, the risk identification there is a process of discovering, identifying and describing the risk. It consists of the possibility of developing all types of hazards: natural and artificial (man-made). The initial stage of risk identification is the recognition and analysis of the risks and hazards using a comprehensive approach.

The next component of risk managing is a risk assessment. For assessing the Risks it is necessary to define and formulate so-called numerical matrix. The disaster risk matrix is defined as a multiplication of the hazard matrix to its consequences.

$$R = H \cdot W \quad (1)$$

In the formula (1) R is a disaster risk matrix; H is a hazard; W is consequences.

To evaluate the risks, it is necessary to identify those social, economic and industrial sectors, which would be exposed under the significant hazards, and at the same time, it should be possible to avoid or reduce them. Risk assessment is the comparing process of the risk analysis results to the risk criteria, for determining the degree of risk. To assess the quality of the risk, it is necessary to define the risk criteria.

Risk criteria are like those parameters, that take into account the significance of the risk estimation. The risk criteria may include related costs and benefits, legal requirements, socio-economic and environmental factors, stakeholder interest, and more.

One of the key factors of risk definition is a hazard. Hazard is defined in the Hyogo Framework for Action as "A potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation".

Hazards can include latent conditions that may represent future hazards and can have different origins: natural or induced by human processes (Man-made hazard). Natural hazards could be divided on geological, hydro-meteorological and biological hazards. Man-made hazards could be divided on environmental degradation and technological hazards.

Hazards could be identified with a probability and intensity (strength) of detection within a definite period, with a speed of development, with a duration, frequency and coverage areas. And, as for the posing to danger, it is the state of persons, population, property, buildings, technology, communications, utilities, transport, energy and other types of systems who may suffer damage or loss as a result of the harmful effects of an emergency.

The signs of an emergency can be divided into:

1. According to the results: human casualties, material damage, violation of living conditions. Based on the results: human casualties, material damage, violation of living conditions.

2. Depending on the nature of the damaging factors: thermal (thermal), chemical, radiation, biological, mechanical, psychological.

3. By the intensity of distribution: sudden, fast, medium, slow (long).

4. By the type of impact: flooding (rising water levels, floods); Degradation of banks, mountain slopes (erosion, abrasion, decomposition, landslides); Impact of mechanical forces (seismic, hydrodynamic impact, excessive pressure of explosion, sudden demolition of the building (construction - structural nature), wind pulsation, body collision; fire; High temperature as a result of thermal radiation, and so on.

In the process of disaster risk management, it is necessary to identify the factors that influence the building structures because of hazards.

Disaster Risks Problem Solution on the Macro level

General aspects of understanding entrepreneurship and innovation in engineering studies. As it is well-known the reduction disaster risk is mostly depending on the quality level of assurance of construction. For receiving a high level of quality of construction modern innovative engineering approaches should be used. Innovative approaches mean using modern entrepreneurship attitudes on the macro level and innovative-researching solutions at the micro-level.

Entrepreneurship attitudes. Main issues of Entrepreneurship attitudes for engineering decisions are Ideation – Creativity, Detecting Problems, Sources of Ideas; Customer Discovery – Customer, Development Customer Creation, Beachhead Market; Value Propositions; Business Model-Canvas; Team Building; Marketing; Prototyping; Intellectual Property; Validation; Company Creation; Elevator Pitch.

In the process of elaboration of MVP-Minimum Viable Product (building structure, bridge and so on) for solving disaster risk problem it is essential to design Business Model Canvas.

Business Model Canvas. Business starts with ideas, wherefrom those ideas the business model is made. [4]. A business model is defined as a model that describes rationally how an organization is built, delivered, can address results/deliver, and get a value [5].

Alexander Osterwalder proposed assessing the business model on nine axes, which are the nine fundamental building blocks of the business model. Each one of these axes will give characterization of certain parts of the company's business model, namely: propositional value / leadership product / value, target customer / market share, complexity channel / channel distribution, customer relationship /customer integration, the configuration / business level of integration model, partnership / network, cost-effective leadership, and revenue model / diversity revenue.

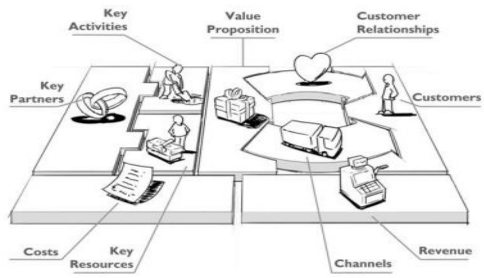


Fig. 1 Business Canvass Model

Business Model Canvas (BMC) is an ontology business model, explaining the characteristics of the business model and allows us to define the entire 'image' of the business model [6].

The focus of this ontology is to have a common language to discuss business models (fig. 1) into practice, implementation, and usability in a business context is one of the goals of the business model [6].

BMC not only discusses the entire process of "modeling business," but also provides something modern, simple, yet quite complete "frameworks" to describe a business in general.

Using these principles, authors considered Building security to start up under the slogan "Save Life & Heritage".

The problems of Market: Only in Europe, there are more than 1000 buildings and constructions of 500 years old. While there are approximately 10 000 of the dangerous plants and constructions. Over 70% of Europe's territory is under extreme pressure influence (snow, rain, wind, landslides, and earthquakes). The most "terrible virus" is a human being. Therefore, time by time, mankind, is losing heritages and every time is under the disaster risk due to Natural hazards and Manmade hazards.

Customers. City councils; Owners of old, historically precious buildings and the constructions with complex architecture; Private owners; Industrial enterprises with dangerous production (nuclear power plants, chemical plants, and factories); Building companies and design engineering organizations as the users of Big Data.

Value Proposition. Reducing disaster risk of the historically valuable buildings and dangerous objects with safety and control during all time of exploitation (24/7/365) on-line.

Problem-solving practical example. To solve this problem, the authors suggest a new type of gyroscope fixed on the disaster risk buildings (see Fig. 2). As a gyroscope may be used equipment type – SaaS (see Fig. 2).

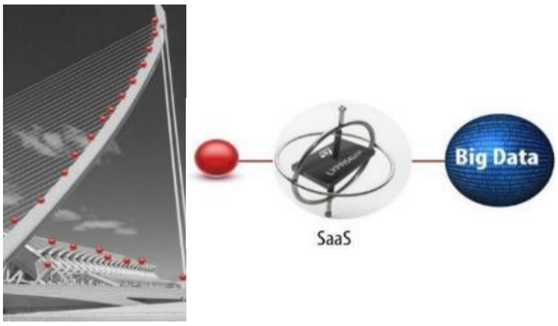


Fig. 2 The Fig structure with gyroscopes

The price of this gyroscope is not expensive (nearly 5 Euros) and the can be used in big quantity on the building. In this process, we should arrange a telecommunication net. Using this net the data from gyroscopes should be received in a big computer and the computer program must automatically elaborate them.

On the left side of picture 333 is depicted a structure with gyroscopes fixed on them. Fixed points or positions of gyroscopes are shown using small red balls. On the right side of the same picture are depicted gyroscope SaaS and the process of combining big data.

Key resources. Gyroscopes, Apps, Telecommunication net, Computers, Head Office,

Costs, Revenue. Table 1 presents the operational profit of the new strut up. These parameters are calculated for three years. Every row indicates accordance Costs, Revenue, and Profit.

Funding during the 1st year. Staff cost– 14 400 Euro; Apps price – 7 000 Euro; Prototyping cost – 8 000 Euro; Advertisement price – 5 000 Euro; Purchase of sensors– 7 500 Euro; Total funding– 41 900 Euro.

Table 1. Operational Profits

Indicators	**1st year**	**2nd year**	**3rd year**
Operational Costs, Euro	7500	64400	133950
Operational Revenue, Euro	10800	84000	177660
Operational Profit, Euro	3300	19600	43710

Impact. The net of the objects is created based on the Internet and things with further analysis of Big Data. The usage of artificial intelligence systems and machine learning for providing the suggestions of the modern constructions.

Competitive advantage. On-line 365/7/24 control of the system; Professional team; SaaS innovative model; Mobility of the hole system; Flexibility of the system; Big Data collected by the team.

Final target – more qualitative and longevous construction.

Ways to reduce the disaster risks caused by flooding and heavy snowfall

As it was mentioned above innovative-researching solutions should be used on the micro-level. The innovative method means use of the modern scientific approaches for receiving best solutions such as Pre-stressing techniques for steel and reinforced concrete structures; to consider stability problems of the rod system in the elastoplastic working region of the materials; using deploying systems in the structures, etc. The main objectives of the study were to develop such approaches that would allow increase of the load carrying capacity of the structures and the reduction of the disaster risks [3] [7].

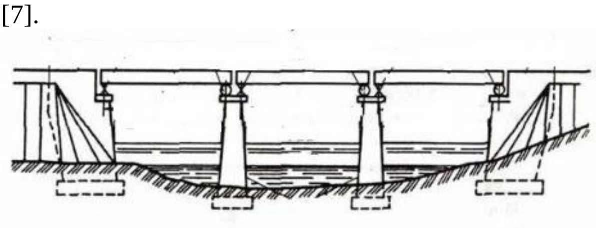


Fig. 3 Bridges with middle supports

Previously conducted analysis indicates that bridge construction technology should be changed in the practice. The bridges built on fast-flowing Mountain and plain rivers have middle supports (Fig.3). This factor creates especially serious problems in the fast-flowing mountain rivers. This leads to potential landslides, mudflows, and flooding in the valleys of rivers [8].

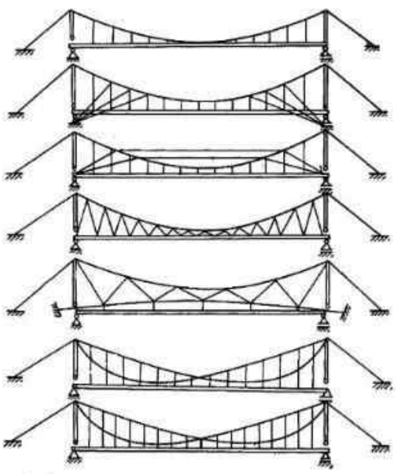


Fig. 4 Suspension bridge systems

The Authors suggested innovative methods for solving this problem. For instance, bridges with suspended structures (Fig.4) or pre-stressed long-span bridges (Fig.5) should be used above the rivers (mountains and plains).

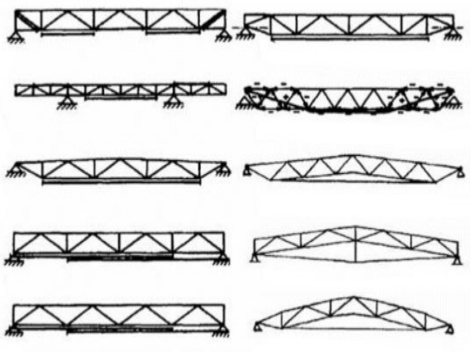


Fig. 5 Pre-stressed systems

These bridges do not require middle supports and they will retain exploitation in a case of washout of riverbeds [3]. The disasters caused by landslides, mudflows, and flooding will be reduced or the risk will equate to zero in this way.

In this direction, the authors have developed "Arch type with a Cable" - new type pre-stressed trusses for different spans (24 m, 27 m, 30 m, 33 m, 36 m, 39 m, 42 m) (Fig. 6). Moreover, the proposed truss differs from existing systems in several constructive advantages, the technical result of which is to increase reliability, reduce weight, increase the span, increase the load-carrying capacity, reduce the prime cost, etc. [9].

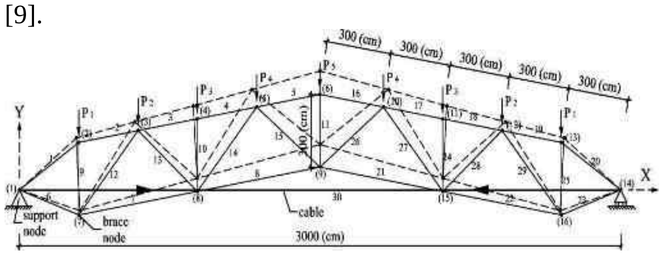


Fig. 6 Laboratory Model of "Arch type" Pre-stressed Truss

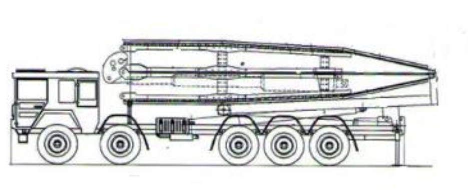
These type pre-stressed trusses may be used to avoid possible threats (hazard) due to heavy snowfall. For example, in big span buildings where conventional roofing systems [10] are used for heavy snowfalls, the risk of disasters caused by their expected destruction can be avoided by using a pre-stressed effect.

Fig. 7 Multi-span inventory bridge

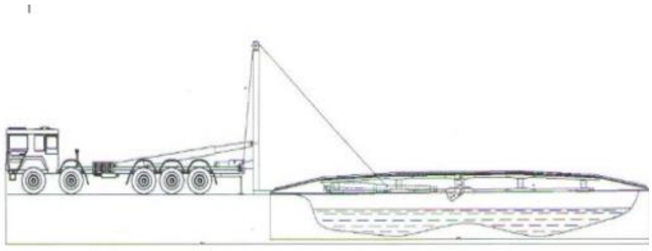
It is important to build and use extreme bridges under conditions of floods, mudflows, and landslides (which operate in the riverbed) [11]. In this direction, the authors have developed the constructions of multi-span inventory bridges, the experimental version of which was used on the River Mtkvari (Fig.7) in Georgia. Special importance is given to the accelerated mechanized bridge construction that will be placed on the truck. Its folded packet is 12 meters and 24 meters in the open state (Fig. 8) [8] [12] [13].

Reducing the risk of disasters caused by earthquakes.

The disaster risk caused by an earthquake is one of the most unexpected and dangerous in comparison with other risks. To avoid this risk, it is necessary to work out very precise calculating methods for the stability of rod systems. A prismatic (rectangular) steel column was studied as a sample that is depicted in Fig. 8.



a)



b)

Fig. 8. Bridge opening scheme
a) the bridge in a folded state; b) the view of the opened bridge

Conducted analysis indicates that the columns of buildings, supports of engineering devices, the drill rods of the oil and gas extraction industry may be subjected to the significant risk of stability loss. Nowadays, there are the design methods based on the test results defining the ratios to avoid this loss of stability risk, but the precision and limits of definition are not always known. The authors suggested the original approach to the issue, in particular, the determination of values of the critical stresses and the finding of the points of the bifurcation were carried out by the tangent established by experimental results, and by the approximation of the so-called double modulus (Fig. 9).

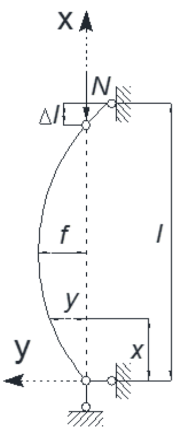


Fig. 9 Compressed Rod

The derived formula of critical stresses for the elastoplastic region of the material was obtained:

$$\sigma_{cr} = \frac{\pi^2 E}{\lambda^2}\left(1-\frac{I_2}{I}\right) + \left(\sigma_{el} - \frac{\lambda_t^2(\sigma_y-\sigma_{el})^2}{2\pi^2 E}\right)\frac{I_2}{I} + \frac{I_2}{I}\sqrt{\left(\sigma_{el} - \frac{\lambda_t^2(\sigma_y-\sigma_{el})^2}{2\pi^2 E}\right)^2 - \sigma_y(2\sigma_{el}-\sigma_y)} \quad (2)$$

Where: σ_{cr}- critical stress; E-modulus of elasticity (Young's modulus); $\lambda = l_0/i_{min}$-slenderness ratio that is equal to the relativity of the effective length of the column to the least of radius gyration; $l_0 = \mu l$ - the effective length of the rod/column; μ- reduction ratio, which depends on the boundary conditions at the ends of the rod/column; the radius of gyration is equal to $i_{min} = \sqrt{I_{min}/A}$; I_{min}-the minimum moment of inertia (the second moment of area) of the cross-section; I and I_2 are moments of inertia of hole and second parts of the cross-section towards the neutral axis. The tangent modulus E_t is obtained as a constant. by the further approximation for this cross-section. σ_{crt} – critical stress in the elastoplastic area; σ_{el} – elastic limit; σ_y -yield strength. Comparative analysis showed the advantage of the proposed approach, particularly, the new critical curves were located below the curves of Engesser-Karman and Shanley and above the critical curves established by building codes. A new approach to the determination of critical stresses in the elastoplastic area was developed through which the structural reliability and economic efficiency were increased compared to the existing approaches (Fig. 10) [14].

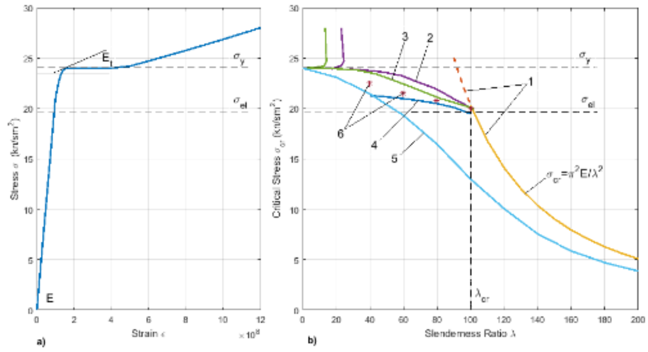


Fig. 10 Stress-strain and Stress-slenderness relations
a) Stress-strain diagram; b) dependence of the critical stresses and the slenderness ratio; 1- Euler's quadratic hyperbola; 2 - Engesser-Karman's model; 3- Shanley's model; 4- Authors approach; 5- a model of building codes; 6- experimental data.

In addition, the calculation of buildings in the elastoplastic area is also important from the economic point of view. The ideology of the building design requires the building to be calculated for an earthquake of two intensities. One will be the design, which is the earthquake during weak exploitation. For example, by 7.0- magnitude. At this time, the building can be calculated within the boundaries of the elastoplastic area of the working of material or during the limited development of plastic deformations. This is the case when the construction keeps the usefulness for exploitation. If an earthquake of 8 - magnitude is likely to be expected. The building should be calculated as elasticity for an earthquake with a magnitude of 8.0. It should be calculated at the elastoplastic stage while plastic deformations are developed with unlimited deformation. i.e. while construction can no longer keep the usefulness for the exploitation.

Predicting disasters

The Sendai Framework also covers the prediction of the risk of disasters. In this regard, the authors have proposed the idea of setting up sensors and gyroscopes on existing and constructive hazardous buildings to obtain data (Fig. 2). Also, it will be important to prepare an appropriate computer program for the automatic processing of the results. Based on the results obtained from the sensors, the authors proposed to prevent the risk of disaster using the method of weak fluctuations. This method involves studying the behavior of a building in weak fluctuations to assess its actual technical state or to determine its dynamic characteristics [15]. It is distinguished by its cheapness, mobility; the authors have developed a mathematical model and the algorithm formulated on it, that uniquely determines how the motions recorded under weak influence should be processed in order to reasonably discuss the behavior of a building during the passage of a real seismic wave (seismography) into its foundation.

III. CONCLUSION

From the results of this study, the following conclusions can be made:

(1) It is recommended to use entrepreneurship approaches on the macro-level for receiving a high level of quality of construction. The structures with entrepreneurship approaches could reduce disaster risk because of its reliability.

(2) It is recommended to use suspension, pre-stressed and other types of innovative systems of bridges, during floods and mudflows; also deployable systems should be used in critical conditions for creating temporary bridges.

(3) It is recommended to use the new approach proposed by the authors to determine the stability of the compressed rod in the elastoplastic region, where the values of the critical stresses (equation (2)) are determined by approximation of the double modulus and the tangent modulus established by the results of experimental studies for reducing disaster risk of earthquake.

(4) It is recommended to use a pre-stressed effect in big span buildings during heavy snowfalls, which makes it possible to increase load carrying capacity and reduce deformations.

(5) It is recommended to use special sensors-gyroscopes and should be installed on buildings having highly responsible requirements and the prospective disaster risks should be predicted during the processing through an automated management system of the received signal.

ACKNOWLEDGMENT

This research was financially supported by the Scholarship program of Georgian National Academy of Sciences, also Erasmus+ Project (No. 573965-EPP-1-2016-1-SE-EPPKA2-CBHE-JP) - InoCENS “Enhancing innovation competences and entrepreneurial skills in engineering education".

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