EJFE

EUROPEAN JOURNAL OF FORMAL SCIENCES AND ENGINEERING

January - June 2020

Volume 3, Issue 1

ISSN 2601-8683 (Print)
ISSN 2601-8675 (Online)

REVISTIA

PUBLISHING AND RESEARCH

EUROPEAN JOURNAL OF
FORMAL SCIENCES AND ENGINEERING

January - June 2020

Volume 3, Issue 1

Typeset by Revistia

ISSN 2601-8683 (Print)
ISSN 2601-8675 (Online)

Address: 11, Portland Road, London, SE25 4UF, United Kingdom

Tel: +44 2080680407

Web: https://ejfe.revistia.org

Email: office@revistia.org

Indexed in Elsevier's Mendeley, WorldCat, RePEc & Ideas, Google Scholar, Microsoft Academics, Index Copernicus, Crossref

International Editorial and Scientific Advisory Board

TABLE OF CONTENTS

ISSN 2601-8683 (Print)
ISSN 2601-8675 (Online)
European Journal of
Formal Sciences and Engineering
January - June 2020
Volume 3, Issue 1

Anomaly-Based Intrusion Detection*:* Feature Selection *and* Normalization Influence *to the* Machine Learning Models Accuracy

Danijela Protić, MSc

Center for Applied Mathematics and Electronics,
Belgrade, Serbia

Miomir Stanković, PhD

Matematical Institute, Serbian Accademy of Science and Arts,
Belgrade, Serbia

Abstract

Anomaly-based intrusion detection system detects intrusion to the computer network based on a reference model that has to be able to identify its normal behavior and flag what is not normal. In this process network traffic is classified into two groups by adding different labels to normal and malicious behavior. Main disadvantage of anomaly-based intrusion detection system is necessity to learn the difference between normal and not normal. Another disadvantage is the complexity of datasets which simulate realistic network traffic. Feature selection and normalization can be used to reduce data complexity and decrease processing runtime by selecting a better feature space This paper presents the results of testing the influence of feature selection and instances normalization to the classification performances of k-nearest neighbor, weighted k-nearest neighbor, support vector machines and decision tree models on 10 days records of the Kyoto 2006+ dataset. The data was pre-processed to remove all categorical features from the dataset. The resulting subset contained 17 features. Features containing instances which could not be normalized into the range [-1, 1] have also been removed. The resulting subset consisted of nine features. The feature 'Label' categorized network traffic to two classes: normal (1) and malicious (0). The performance metric to evaluate models was accuracy. Proposed method resulted in very high accuracy values with Decision Tree giving highest values for not-normalized and with k-nearest neighbor giving highest values for normalized data.

Keywords: feature selection, normalization, k-NN, weighted k-NN, SVM, decision tree, Kyoto 2006+

Introduction

Over the past decades the network security has changed with threats becoming far more complex moving from basic attacks against one device to network intrusion attacks against organizations networks. A network intrusion attack is defined as any use of a computer network that compromises network security. Intruders try to gain unauthorized access to files or privileges, modify and destroy the data, or render the computer network unreliable (Aissa & Guerroumi, 2016, 1091). The goal of intrusion detection is to build a system which would scan network activities and generate alerts if either a specific attack occurred or an anomaly in the network behavior detected. Intrusion detection system (IDS) monitors the computer network searching for any suspicious activities that indicate intrusions. In anomaly-based detection base line is what is considered a 'normal' traffic and then flag anything that is not normal as 'abnormal'. The mechanism of anomaly-based IDS depends on the observation to classify input data into classes by adding labels. In a binary classification problem, a single instance can only be divided into two classes. Machine Learning (ML) - based IDS use ML classifiers to learn system normal behavior and build models that help in classifying inputs into the two classes: normal (1) or potentially malicious anomaly (0).

A supervised ML algorithm takes a known set of input data and known responses to generate reasonable predictions for unknown data. In this paper we present four ML algorithms: Gaussian Support Vector Machine (SVM) (Burgess, 1998, 291), Decision Tree (Sebastiani, 2002, 13), k-Nearest Neighbors (k-NN) and weighted k-Nearest Neighbors (wk-NN) (Hechenbichler & Schliep, 2004). k-NN predictions assume that objects near each other are similar. Euclidean distance metric is used to find nearest neighbor. SVM classifies data by finding the linear decision boundary that separates all data points of one class from those of another class. A decision tree predicts responses to data by following the decisions in the tree from the root down to a leaf node. A tree consists of branching conditions where the value of predictor is compared to a trained weight. However, ML algorithms are computationally expensive if they are trained with the set that has a large number of features. The solution to this problem is to reduce feature space and train classifiers only with the reduced subset. In this paper we present algorithms for feature selection based on preprocessing the Kyoto 2006+ dataset. All categorical features are removed, as well as all features related to the duration of the connection and number of bytes transmitted from source to destination and vice versa. Also, all features containing instances which could not be normalized into the range [-1,1] are cut. Two subsets are generated one consisting of 17 features which contain not-normalized instances and another consisting of nine features of normalized instances. After the training and testing the datasets, accuracy is used to determine performances of the models.

1 Anomaly-Based Intrusion Detection Systems

Anomaly-based IDS monitors computer network to detect intrusion based on

irregularities in the pattern with the respect to the normal pattern. It creates a model behavior of the system and then looks for activities that differ from the created model. The anomaly detection approach looks for variations and deviations from an established baseline behavior which might indicate malice. If any anomaly in network activities occurs the IDS warns the system administrator of potentially intrusive action. Anomaly detection can be split into two main methods: machine learning method and rule-based method. ML methods are used to train classifiers in order to recognize what is the notion of normality and then rule-based methods identify abnormal network traffic and flag anomaly.

The main advantage of anomaly based IDS is its ability to detect new attacks even when there is no complete information about the type of attack (Modi et al., 2013, 46). The second advantage is that profile of normal activity is customized for particular computer network and therefore making it very difficult for attacker to know what is certainly what activities it can carry out without getting detected (Patcha & Park, 2007, 3449). One of the biggest advantages of anomaly-based IDS is its ability to detect zero-day attacks since it does not depend on an established signature dataset. The most fundamental challenge is to identify what is normal. Another issue is that even if everything seems like normal over time there are some legitimate anomalies that can be identified as abnormal. Moreover, triage is complex. If one wants to identify an attack an anomaly-based IDS may be very hard to figure out what caused the trigger happened. Furthermore, anomaly-based IDS generates a large number of false positive alarms, since user or network behavior is not always known in advance (Kajal & Devi, 2013, 16). It also requires time to establish baseline behavior when it is first placed in a new network environment or host device. One of the main problems of anomaly-based technique is the selection of the appropriate set of system features because the activities are mostly ad hoc and experience based. Finally, the drawback is also their expensive nature (Garcia-Teodoro et al., 2009, 21).

2 Feature Selection and Instances Normalization

For the purpose of this study two datasets were generated, both based on feature selection and transformation of the Kyoto 2006+ dataset. The Kyoto 2006+ dataset contains daily records of real network traffic data recorded from 2006 to 2009. Each instance in the dataset is labeled with 14 statistical features derived from the KDD Cup '99 dataset (KDD CUP '99 dataset, 1999) and 10 additional features which can be used for further analysis and evaluation of the anomaly-based IDS (Protić, 2018, 587-588). The Kyoto 2006+ dataset is given in the Table 1.

Table 1 The Kyoto 2006+ dataset

No	Feature	Description
1	Duration – basic	The length of the connection (seconds).
2	Service – basic	The connection's server type (dns, ssh, other).
3	Source bytes – basic	The number of data bytes sent by the source IP

		address.
4	Destination bytes – basic	The number of data bytes sent by the destination IP address.
5	Count	The numbers of connections whose source IP address and destination IP address are the same to those of the current connection in the past two seconds.
6	Same_srv_rate	% of connections to the same service in the Count feature.
7	Serror_rate	% of connections that have 'SYN' errors in Count feature.
8	Srv_serror_rate	% of connections that have 'SYN' errors in Srv_count (% of connections whose service type is the same to that of the current connections in the past two seconds) features.
9	Dst_host_count	Among the past 100 connections whose destination IP address is the same to that of the current connection, the number of connections whose source IP address is also the same to that of the current connection.
10	Dst_host_srv_count	Among the past 100 connections whose destination IP address is the same to that of the current connection, the number of connections whose service type is also the same to that of the current connection.
11	Dst_host_same_src_port_rate	% of connections whose source port is the same to that of the current connection in Dst_host_count feature.
12	Dst_host_serror_rate	% of connections that have 'SYN' errors in Dst_host_count feature.
13	Dst_host_srv_serror_rate	% of connections that have 'SYN' errors in Dst_host_srv_count feature.
14	Flag	The state of the connection at the time of connection was written (tcp, udp).
15	IDS_detection	Reflects if IDS triggered an alert for the connection; '0' means any alerts were not triggered and an Arabic numeral means the different kind of alerts. Parenthesis indicates the number of the same alert.
16	Malware_detection	Indicates if malware, also known as malicious software, was observed at the connection; '0' means no malware was observed, and string indicates the corresponding malware observed at the connection. Parenthesis indicates the number of the same malware.
17	Ashula_detection.	Means if shellcodes and exploit codes were used in the connection; '0' means no shellcode or exploit

		code was observed, and an Arabic numeral means the different kinds of the shellcodes or exploit codes. Parenthesis indicates the number of the same shellcode or exploit code
18	Label	Indicates whether the session was attack or not; '1' means normal. '-1' means known attack was observed in the session, and '-2' means unknown attack was observed in the session.
19	Source_IP_Address	Means source IP address used in the session. The original IP address on IPv4 was sanitized to one of the Unique Local IPv6 Unicast Addresses. Also, the same private IP addresses are only valid in the same month; if two private IP addresses are the same within the same month, it means their IP addresses on IPv4 were also the same, otherwise are different.
20	Source_Port_Number	Indicates the source port number used in the session.
21	Destination_IP_Address	It was also sanitized.
22	Destination_Port_Number	Indicates the destination port number used in the session.
23	Start_Time	Indicates when the session was started.
24	Duration	Indicates how long the session was being established.

(Source: Song et al., 2011)

The Kyoto 2006+ dataset was captured using honeypots, darknet sensors, e-mail servers, web crawler and other computer network security systems deployed on five networks inside and outside Kyoto University. During the observation period 50.033.015 sessions of normal traffic, 43.043.225 sessions of known attacks and 425.719 sessions of unknown attack were recorded. The dataset consists of both numerical and categorical features.

Complexity of the Kyoto 2006+ dataset is reduced by elimination of irrelevant features and normalization of instances. In this research normalization executed the following transformation on original instance values

$$tansig(n) = \frac{2}{1 + e^{-2 \cdot n}} - 1$$

where n represents the number of instances.

The following preprocessing scheme is proposed:

Cut all categorical features - resulting subset contains 17 features (1, 3, 4-17, 24);

Remove statistical features related to the duration of the connection and the number of Source↔Destination bytes (1, 3, 4, 14),

Cut all the features used for further analysis and evaluation of the models (15-17, 24);

Remove features containing instances which could not be normalized into the range [-1, 1] - resulting subset contains nine features (5-13);

Feature 18 ('Label') is used to categorize network traffic into two categories: normal (1) and anomalous (0).

Experiments were carried out on both generated subsets. Number of features in the first subset is approximately three quarters the size of features in the Kyoto 2006+ dataset. Number of features in the second subset contains less than 40% of the original dataset size and is almost a half the size of features in the first subset.

3 Results

In the experiments Classification Learner is used to train and test Gaussian SVM, Decision Tree, k-NN and wk-NN models. Models are chosen because of the following characteristics: prediction speed, memory usage, interpretability and flexibility of the model. (See Table 2)

Table 2 Classifiers characteristics

Model	Prediction speed	Memory usage	Interpretability	Model Flexibility
Tree	Fast	Low	Easy	Medium. Medium number of leaves for finer distinctions between classes (maximum number of splits is 20).
SVM	Fast	Medium	Hard	Medium. Medium distinctions, with kernel scale set to sqrt(P).
k-NN	Medium	Medium	Hard	Medium. Medium distinctions between classes. The number of neighbors is set to 10.
wk-NN	Medium	Medium	Hard	Medium. Medium distinctions between classes using a distance weight. The number of neighbors is set to 10.

(Source: MathWorks, 2016.)

Experiments were carried out on 10 daily records from the Kyoto 2006+ dataset. The minimum number of records per day was 57.287, while the maximum number of records per day was 158,572.

After the training and testing accuracy was used to determine performances of the models. Accuracy represents the overall success rate, i.e. the ratio between numbers of correct predictions to the total number of classifications, which can be calculated as

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

where:

TP (True Positive) represents the number of correctly classified anomaly as anomaly;

FN (False Negative) occurs when classifier incorrectly classifies anomaly as normal behavior;

FP (False Positive) occurs when classifier incorrectly classifies normal behavior as anomaly;

TN (True Negative) represents the number of correctly classifies normal behavior as normal;

Table 3 shows the results of the accuracy for datasets containing nine and 17 features, respectively.

Table 3 Accuracy of medium k-NN, wk-NN, medium Gaussian SVM and medium decision tree models

No	Size	Model	Accuracy - 9 features	Runtime	Accuracy - 17 features	Runtime
1	158572	k-NN	98.3%	275.72s	99.0%	1000.8s
		wk-NN	98.4%	277.32s	99.1%	1019.15s
		SVM	98.1%	449.35s	98.4%	467.7s
		Tree	97.2%	3.8452s	98.4%	14.241s
2	129651	k-NN	91.8%	175.84s	98.8%	695.88s
		wk-NN	91.8%	173.32s	99.0%	691.08s
		SVM	98.3%	254.32s	98.4%	304.56s
		Tree	97.3%	3.3104s	99.7%	9.4989s
3	128740	k-NN	98.2%	193.82s	98.6%	682.07s
		wk-NN	98.1%	194.81s	98.8%	690.58s
		SVM	97.8%	280.82s	97.9%	379.61s
		Tree	97.2%	3.3033s	99.8%	9.5367s
4	136625	k-NN	99.3%	194.83s	99.5%	782.1s
		wk-NN	99.4%	194.23s	99.7%	788.11s
		SVM	99.1%	217,32s	99.3%	234.59s
		Tree	98.3%	8.3169s	99.7%	10.001s
5	90128	k-NN	99.0%	101.28s	98.5%	731.2s
		wk-NN	99.1%	101.753s	99.6%	744.15s
		SVM	99.0%	86.283s	99.3%	230.33s
		Tree	98.4%	2.2308s	99.7%	10.855s
6	93999	k-NN	96.5%	109.25s	99.4%	354.09s
		wk-NN	96.5%	108.77s	99.5%	351.55s
		SVM	98.0%	111.83s	98.4%	149.03s
		Tree	97.5%	2.2613s	99.5%	6.9921s
7	80807	k-NN	98.8%	91.25s	99.4%	285.77s
		wk-NN	98.8%	91.267s	99.5%	285.25s
		SVM	97.9%	227.28s	98.1%	125.25s

		Tree	98.9%	2..2615s	99.4%	6.2339s
8	57278	k-NN	99.6%	42.704s	99.3%	77.224s
		wk-NN	99.3%	43.235	99.3%	77.121s
		SVM	99.2%	33.754s	99.1%	31.211s
		Tree	99.3%	1.743s	99.4%	3.7448s
9	58317	k-NN	99.1%	31.714s	99.3%	133.92s
		wk-NN	99.2%	31.738s	99.4%	134.4s
		SVM	99.1%	34.234s	99.2%	36.907s
		Tree	98.9%	1.7482s	99.5%	4.4372s
10	57278	k-NN	99.4%	43.734s	99.6%	129.99s
		wk-NN	99.5%	43.272s	99.6%	130.88s
		SVM	99.2%	30.239s	99.3%	37.894s
		Tree	99.4%	1.7489s	99.7%	4.4535s

Results show very high accuracy with decision tree giving high values for not-normalized data. In this case accuracy varies from 99.4% to 99.8%. wk-NN gives the highest value for normalized data (99.5%) followed by decision tree (99.3%), Gaussian SVM (98.3%) and k-NN (98.2%) models (see Table 4).

Table 4 The highest accuracy of k-NN, wk-NN, Gaussian SVM and decision tree models

Model	Accuracy - 9 features	Runtime	Accuracy - 17 features	Runtime
k-NN	98.2%	193.82s	99.6%	129.99
wk-NN	99.5%	43.272s	99.7%	788.11s
SVM	98.3%	254.32s	99.3%	37.894s
Tree	99.3 %	1.743s	99.8%	9.5367s

Results show the highest accuracy of the decision tree model and 17 features selected. wk-NN gives the highest value for the second subset. Runtime of the decision tree models is significantly shorter than runtime of other models. Runtime of the second subset is up to four times shorter than runtime of the first subset.

Conclusions

Feature selection and instances normalization were used to preprocess Kyoto 2006+ dataset. Two subsets were built, one containing 17 features and not-normalized instances and another containing nine features and normalized instances. Classification Learner was used to train k-NN, wk-NN, Gaussian SVM and the decision tree models. Proposed methods resulted in very high accuracy with decision tree giving the highest accuracy value and the shortest runtime for the subsets containing 17 features. wk-NN method resulted in the highest accuracy value and four times shorter runtime for the subsets consisting nine features.

References

[1] Aissa, N.B. & Guerroumi, M. (2016). Semi-Supervised Statistical Approach for Network Anomaly Detection. Procedia Computer Science, 83, 1090-1095.

[2] Burgess, M. (1998). Computer Immunology. 12th USENIX Conference on System Administration, Boston, MA, USA, 06-11 December 1998, 283-298.

[3] Garcia-Teodoro, P., Diaz-Verdejo, J., Macia-Fernandez, G. & Vasquez, E. (2009). Anomaly-based network intrusion detection: Techniques, systems and challenges. Computers & Security 28(2009), 8-28.

[4] Kajal, R. & Devi, S. (2013). Intrusion Detection Systems: A Review. Journal of Network and Information Security, 1(2), 15-21.

[5] KDD CUP '99 dataset. (1999, October 28). Retrieved from http://kdd.ics.uci.edu/databases/kddcup99/kddcup99.html

[6] Hechenbichler, K. & Schliep, K. (2004). Weighted k-Nearest-Neighbor Techniques and Ordinal Classification. Sonderforschungsbereich 386, Paper 399 (2004). Retrieved from https://epub.ub.uni-muenchen.de/1769/1/paper_399.pdf

[7] Modi, C., Patel, D., Borisaniya, H., Patel, A. & Rajaran, M. (2013). A survey of intrusion detection techniques in Cloud. J. Netw. Comput. App. 36(1), 42-57.

[8] Patcha, A. & Park, J.-M. (2007). An overview of anomaly detection techniques: Existing solutions and latest technological trends. Computer Networks 51(2007), 3448-3470.

[9] Protić, D. (2018). Review of KDD Cup '99, NSL-KDD and Kyoto 2006+ datasets. Vojnotehnički glasnik/Military Technical Courier, 66(3), 580-596. DOI: 10.5937/vojteh-16670.

[10] Sebastiani, F. (2002). Machine learning in automated text categorization. ACM Comput.Surv. 34(1),1-47.

[11] Song, J., Takakura, H., Okabe, Y., Eto, M., Inoue, D. & Nakao, K. (2011). Statistical Analysis of Honeypot Data and Building of Kyoto 2006+ Dataset for NIDS Evaluation. In: Proc.1st Work-shop on Building Anal. Datasets and Gathering Experience Returns for Security. Salzburg. April 10-13, 29-36.

ISSN 2601-8683 (Print)
ISSN 2601-8675 (Online)
European Journal of
Formal Sciences and Engineering
January - June 2020
Volume 3, Issue 1

Experimental and Numerical Investigation for Mechanical Ventilated Greenhouse (Comparison between Different Turbulence Models)

Ahmed E. Newir

Mechatronics Engineering Department,
Faculty of Engineering, October 6 University, Egypt

Mohamed A. Ibrahim

Mechatronics Engineering Department,
Faculty of Engineering, October 6 University, Egypt

Abstract

Using computational fluid dynamics (CFD) in agriculture field especially in designing greenhouses is becoming ever more important to reduce the energy consumption, wherefore a comparison between the experimental and numerical results increasing the credibility of theoretical studies and therefore depending on it. Forced ventilation greenhouse has been used in even span greenhouse to study the experimental measurements of temperature distribution in summer rush hours, the experiment has been performed in October 6 University, Giza, Egypt. More than one turbulence models (Standard K-ε, RNG K- ε, Reynolds Stress Model (RSM), Transition Shear-Stress Transport (SST), Standard K-ω and K-KL-ω) are used for the (CFD) numerical study implemented for comparison between the experimental and numerical measurements. After this study can get that SST turbulence model is the most efficient numerical solution for this case, a good qualitative and quantitative agreement found between the numerical results and the experimental measurements.

Keywords: Greenhouse; Mechanical ventilation; CFD.

Introduction

Operating mechanical ventilation effects on the yield and quality of almost all greenhouse crops. Mechanical ventilation is used to reduce the greenhouse effect inside the greenhouse during the hot days, which leads to attain the optimum crops temperature with minimum power. The numerical solution allows to make changes to the geometrical shape and method of mechanical ventilation by computational fluid

dynamics (CFD) to reach the ideal solution for mechanical ventilation which provides better efficiency.

The first user for an early version of a CFD model to predict the distributions of climatic factors inside and outside small naturally ventilated greenhouses is Okushima (Okushima, Sase, & Nara, 1989). Two equation K-ϵ model is used to computed air flow distributions compared with the wind–tunnel results of S. Sase et al. (Sase & Takakura, 1984), which made different openings in the roof and side walls. While the experimental results showed little correlation with the computational model, the study demonstrated the possibility of using a CFD model to predict environmental distributions for naturally ventilated greenhouses.

I. B. Lee and T. H. Short (Lee & Short, 2000) studied two-dimensional K-ϵ model to validate the experimental data for multi-span greenhouse in different velocity inlet at 0.9 m/s and 2.5 m/s, validation made with only four air temperatures sensors across the 33 m * 35 m multi-span greenhouse, which means a simple understanding of temperature distribution in the greenhouse. The maximum error between the experimental measurements and numerical data was 3.2%.

Campen et al. (Campen & Bot, 2003) show that the three-dimensional calculations are preferable over the two-dimensional calculations, for computational assessment of ventilation rate with wind direction. Crop not considered in the model since no crop grown during the experiments. The calculations resembled experimental data within 15%. The wind speed correlated linearly with ventilation rate for both configurations without the buoyancy effect, which goes with the basic theory on ventilation. The CFD calculations used the standard K-ϵ model and indicated that ventilation rate for both configurations is largely dependent on wind direction, which is also observed in the experimental investigation.

The results for four different configurations of ventilators in different ventilation rates and different airflow and temperatures patterns is investigated by T. Bartzanas et al. (Bartzanas, Boulard, & Kittas, 2004). The presented results indicate that the highest ventilation rates are not always the best criterion for evaluating the performance to the agriculture crops in the greenhouses. The standard K-ϵ model remains the standard model used in the modeling of agricultural structures and applications.

J. Flores-Velazquez et al. (J. Flores, Montero, Baeza, & Lopez, 2014) used CFD with a standard K-ϵ model to study more than one aspect, the rate of air change with different ventilation opening in the roof, air speed, humidity and temperature distribution. The temperature measurements inside the greenhouse with three sensors for the greenhouse area 7.5 * 28 m. This area is large to monitor the change in temperature, which is observed in the theoretical study that there is a temperature difference of almost 15 k and these difference could not predict in the experimental measurements, due to the limitation of temperature measuring instruments. Increasing the speed of mechanical ventilation not recommended because it may lead to loss of crops.

Previous studies have studied the natural and mechanical ventilation in terms of different air speeds, air change rates, roof and side walls openings, but did not sufficiently studied the temperature distribution in experimental and numerical investigations, which is the direct effect on plants and crops in the greenhouse. In previous works computational fluid dynamics (CFD) is used in mechanical and free ventilation of the greenhouses, found some time gaps in the literature CDF studies due to low computational capability of the CFD programs and the limited computing power available at that time. Especially, they failed to describe in detail the effects of fluctuating turbulent airflow and the temperature distribution on the air exchange of the greenhouses with their CFD model.

The objectives of the present study are to verify three-dimensional CFD numerical simulations for different turbulence models (Standard K-ε, RNG K- ε, Reynolds Stress Model (RSM), Transition Shear-Stress Transport (SST), Standard K-ω and K-KL-ω) with air temperature distributions along the greenhouse axis and to compare experimental temperature measurements in a full–scale, mechanical ventilated, even–span greenhouse. Verification tests are during summer day for hot and clear sky.

Experimental Setup

The experiments located at October 6 University, Giza, Egypt (longitude angle of 29.98°and latitude angle of 30.95°). The measurements are conducted during peak sunshine hours between 10:00 AM and 5:00 PM. The greenhouse has inclined roof type even span greenhouse. The frame is made of rectangular iron pipes and Polycarbonate sheets covering material. The greenhouse with an effective floor 3.6x2.4 m^2 with central height 2.4 m and side walls height 1.8 m as shown in figure 1.

A fan of 350 mm sweep diameter and 1360 rpm with a rated air volume flow rate of 3200 m^3/h is provided on the south wall of the greenhouse for the forced convection experiments.

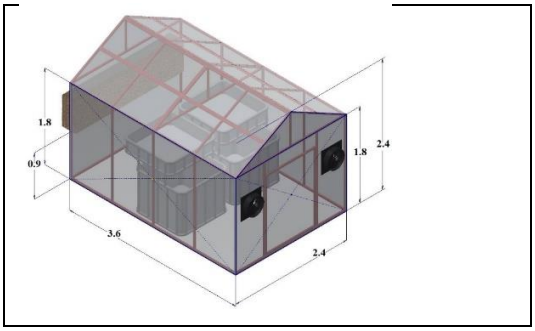
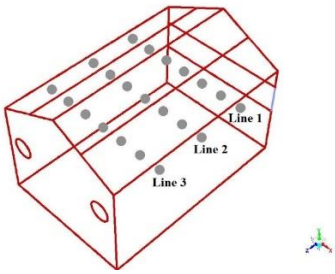
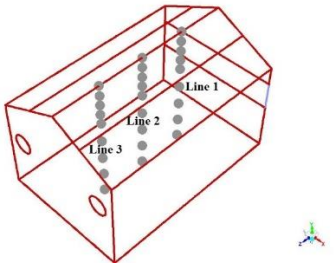


Figure 1 Schematic diagram of the greenhouse (dimensions are in m).

Temperature measurement is the most important parameter in the greenhouse. Therefore, good distribution of the position of the temperature measurement sensors is necessary to study the temperature variation inside the greenhouse.



Horizontal Measurements Lines



Vertical Measurements Lines

Figure 2 Horizontal and vertical measurements lines.

The temperature sensors are installed in vertical and horizontal lines as shown in figure 2. The positions are 1.6 m and 1.2 m for the horizontal and vertical lines respectively. The vertical and horizontal lines distributed inside the greenhouse in three positions; the first quarter, middle and third quarter sections.

Greenhouse walls temperature measured by 7 (DS18B20) temperature sensor one for each wall and two for the even span roof. In each horizontal line locate seven temperature sensors 0.4 m apart and for the vertical line 9 temperature sensors distributed in two parts, five sensors are used for the bottom part the distance between each of them is 0.4 m, and the top part consists of 4 sensors with 0.2 m apart. Two temperature sensors are used to measure outside and inside temperature.

Mathematical modelling

The three-dimensional model of greenhouse structure is established in this study. The cooling pads shape in the ventilation opening and the internal support structure have a small effect on the internal greenhouse temperature, so they are ignored in simplification processing. The ventilation opening placed on the northern wall to reach the maximum cooling effect using the minimum ventilation. The temperature environments for simulation calculation are in hot summer with no wind. Forced ventilation is performed by fan for greenhouses cooling. Entire greenhouse model is divided into 2 million elements. The grid test results show good grid quality. Iterative calculation is conducted using two CPU 3.07 GHz quad-core workstation in simulation.

The governing equations of fluid flow and heat transfer can considered as mathematical formulations of the conservation laws that govern all associated phenomena. These conservation laws describe the rate of change of a desired fluid property as a function of external forces and can written as:

Continuity equation: the mass flows entering a fluid element must balance exactly with those leaving.

$$\frac{\partial \rho}{\partial t} + \nabla \cdot [\rho \vec{V}] = S_m$$

Where ρ is the air density, t is the time, $\vec{v}$ is the velocity vector and S_m is the source term.

Conservation of momentum (Newton's second law): the sum of the external forces acting on the fluid particle is equal to its rate of change of linear momentum.

$$\frac{\partial}{\partial t}(\rho \vec{v}) + \nabla \cdot (\rho \vec{V} \vec{V}) = -\nabla p + \rho \vec{g} + \vec{F}$$

Where p is the static pressure and $\vec{g}$ and $\vec{F}$ are the gravitational body force and external body forces respectively.

Conservation of energy (the first law of thermodynamics): the rate of change of energy of a fluid particle is equal to the heat addition and the work done on the particle.

$$U_j \frac{\partial T}{\partial x_j} = \frac{\partial}{\partial x_j}\left(\alpha \frac{\partial T}{\partial x_j} - \overline{u_j t}\right)$$

The solution method is run to make the control parameter settings of model in the requirement section. The SIMPLE scheme is used in this study in order to make computing convergence faster. Pressure, momentum, turbulent kinetic energy, turbulent dissipation rate, energy and radiation (discrete ordinate) all used second-order upwind for more accurately calculate, and relaxation factor settings are as shown in Table 1.

Table 1 Relaxation factor settings of the solution method.

Pressure	Density	Body Force	Momentum	Turbulent Kinetic Energy	Turbulent Dissipation Rate	Turbulent Viscosity	Energy	Discrete Ordinate
0.4	1	1	0.7	0.8	0.8	0.9	0.9	0.9

The starting point for all problems is a "geometry." Geometries can created using the ANSYS ©17.1 DESIGN MODULER pre-processor software, which is used to create the grid.

A good quality mesh verifies the fast and accurate solution. Therefore, more than one mesh type is tested and compared with each other to attain a good computational fluid dynamics solution. The different mesh methods are multi-zone, automatic, tetrahedral patch conforming and tetrahedral patch independent. Mesh quality depending on more than one parameter; the important two parameters is meshed elements and maximum mesh skewness ratio to ensure that:

The mesh density should be high enough to capture all relevant flow features.

The mesh adjacent to the wall should be fine enough to resolve the boundary layer flow.

The best method for the greenhouse geometry is tetrahedral patch independent with 4.4 million elements with maximum skewness 0.599 which falls into the "good" range, according to the software standard.

The inlet air conditions are taken as the experiment conditions 33.25ºC. The inlet is set as velocity inlet conditions with velocity inlet 0.25 m/s and the turbulence intensity could be assumed to be 5%, and the hydraulic diameter is assumed to be 0.8949m.

The air outlets are set as pressure outlet conditions. Pressure outlet boundary conditions are used to define the static pressure at flow outlets (and also other scalar variables, in the case of backflow). The temperature of outlet air is 40°C, and the turbulence intensity could be assumed to be 5%, and the hydraulic diameter is assumed to be 0.35m.

The greenhouse roof and walls in the model are 0.006m thickness double layer polycarbonate glazing material and adding in ANSYS the material properties, it is properties is 1210 kg/m^3 density, 1200 J/kg-k specific heat and 0.21 w/m-k thermal conductivity. The walls temperature condition shown in table 4-4 as the experimental measurements.

Table 2 Greenhouse walls temperature measured at 12:00 pm for case 2.

Wall	Temperature (°C)
Right roof temperature	42.75
left roof temperature	41.75
Floor temperature	33.75
Front wall temperature	45.75
Right wall temperature	41
Back wall temperature	45.75
Left wall temperature	36.75
Outside temperature	42.75

Results and discussion

The working of the greenhouse started at 9 am on the day of the 25 August to ensure that the best representation of the mechanical ventilation inside the greenhouse kept at the peak time in the experimental measurements. The location of the greenhouse (latitude and longitude) and the experiment time introduced in the CFD program to show the radiation effect inside the greenhouse theoretically.

One of the most important applications of this study is to investigate the best turbulence model can use through CFD to control the temperature distribution inside the greenhouse.

The first three models (Standard K-ε, RNG K- ε and Reynolds Stress Model (RSM)) compared with the experimental work as shown in figure 3. The second three models (Transition Shear-Stress Transport (SST), Standard K-ω and K-KL-ω) compared with the experimental work as shown in figure 4.

The Reynolds Stress Model (RSM) seems to have the nearest results comparing which the experimental results. In horizontal line 1, the average temperature difference between the experimental measurements and numerical calculations is about 9%. The largest temperature difference percent is 18.6% in the middle of the horizontal line. The least difference is 0.7% on the west wall.

For the vertical line 1 in figure 3, the RNG K- ε has the nearest results comparing to the experimental measurements. The temperature difference percent in the range of 0.9% to 19% with an average value of 10.6%.

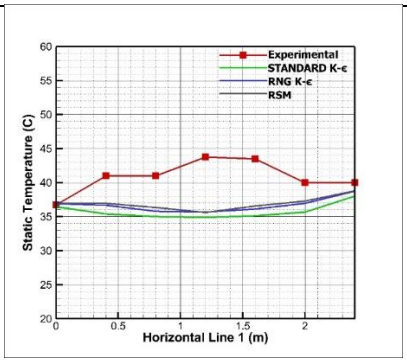
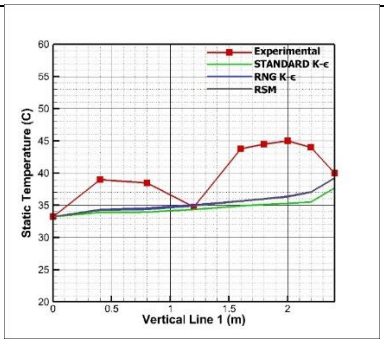
The percentage difference value calculated as:

$$\%\, value = \frac{t_{num} - t_{exp}}{t_{exp}} \times 100$$

Where:

t_{num} : the numerical temperature results

t_{exp} : the experimental temperature measurements

Horizontal Lines	Vertical Lines
	

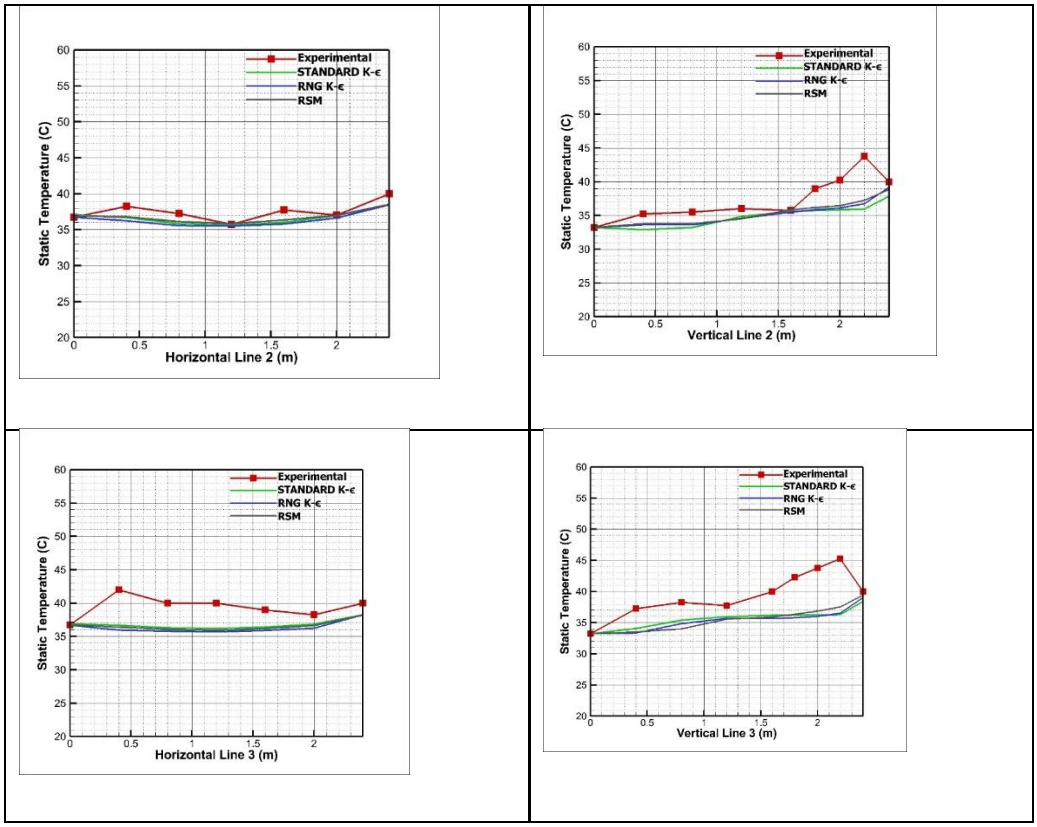
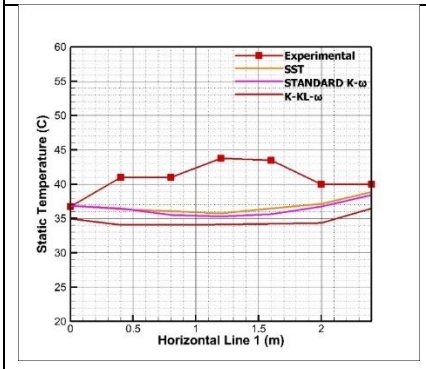
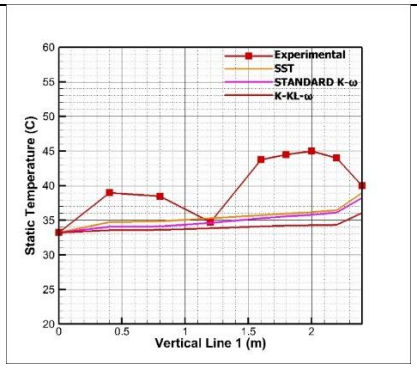


Figure 3 Experimental and numerical comparison for temperature variation at horizontal and vertical lines.

Horizontal Lines	Vertical Lines
	

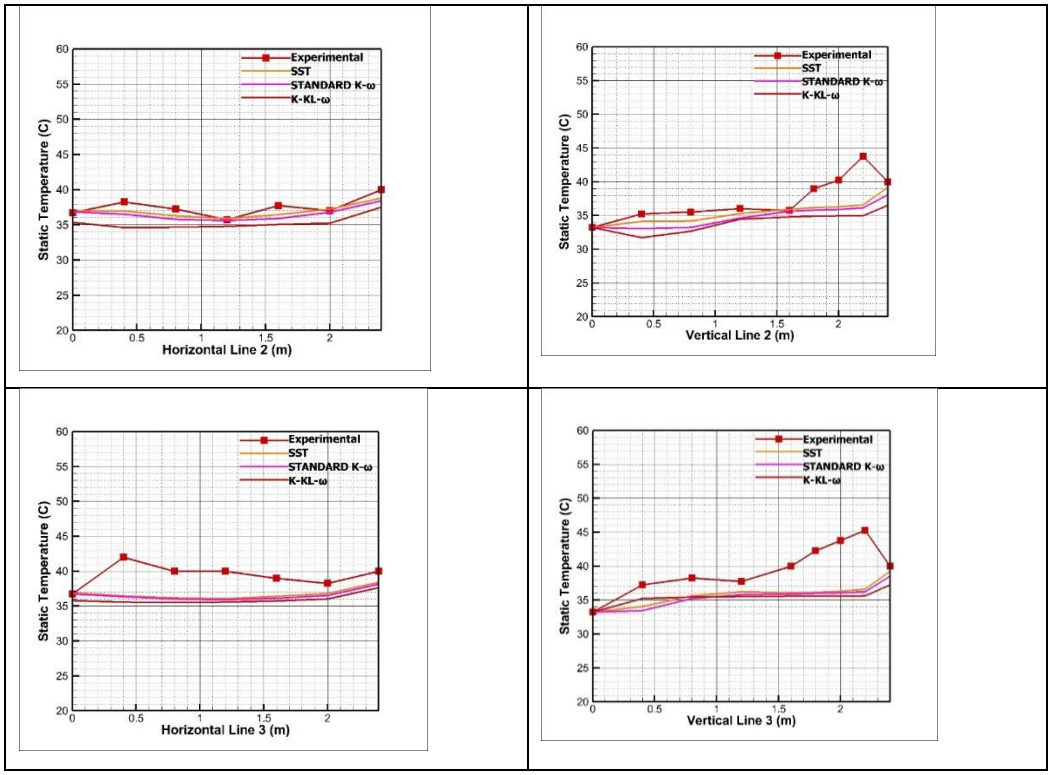


Figure 4 Experimental and numerical comparison for temperature variation at horizontal and vertical lines.

The highest temperature difference found at height 2m in the triangle zone under the even span roof. This increase is due to the effect of the greenhouse effect at the top of the greenhouse. Therefore, there is always a discrepancy between the experimental measurements and the numerical calculations in this region. The temperature difference between the experimental measurements and numerical solution is about zero at the points 0 m, 1.2 m, and 2.4 m.

In horizontal line 2, it can notice that small average temperature difference between the experimental measurements and numerical calculations especially for SST model as shown in figure 4, the average percentage difference is 1.48%. The largest temperature difference is 3.39%, and the minimum is 0.75%.

For the vertical line 2 the lowest temperature difference between the experimental measurements and numerical calculations for SST model as shown in figure 4, the average temperature difference is 4.85%, where the least and the greatest values are 0.49% and 16.38% respectively.

As shown in figure 3 in the third horizontal line, the nearest solution to the experimental results applying the standard K-ε model. The average temperature difference is 6.5% where the least temperature difference is 0.45%, and the maximum is 12.6%.

SST model is the nearest solution for the third vertical line. The average temperature difference is 9% for the highest value of the temperature difference which is 19%, and the lowest value is 1.9%.

The effect of the sun's movement between east and west shown in the horizontal lines in figure 3 and 4. There is a temperature difference between the east and west sides is 3.25°C in the experimental measurements. The corresponding value for the numerical study is 1.4°C.

Also saw on the vertical lines in figure 3 and 4 the temperature difference is raised from the surface of the ground and the greatest height of the greenhouse and significantly the greenhouse effect, especially from the height of 1.5 m to the highest level of the greenhouse.

Comparison between all models, the results are shown in figure 5, one can conclude that the most efficient turbulence models in the SST model.

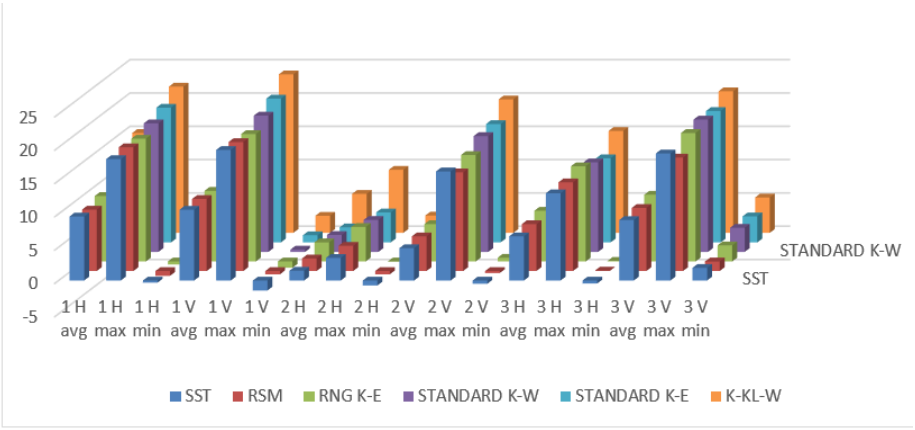


Figure 5 Percentage temperature difference between the experimental measurements and different turbulence models.

Conclusion

The influence of mechanical ventilation of an even-span greenhouse is numerically investigated using commercial fluid dynamics code. A good qualitative and quantitative agreement is found between the numerical results and the experimental measurements.

Must check different turbulence modules to find the suitable one, so six turbulence models applied in the present theoretical study: Standard K-ε, RNG K- ε, Reynolds Stress Model (RSM) and Transition Shear-Stress Transport (SST), Standard K-ω and K-KL-ω.

The effect of mechanical ventilation of an even-span greenhouse numerically investigated using commercial fluid dynamics code. A good qualitative and quantitative agreement found between the numerical results and the experimental measurements. The deviation between the two results was about 8% for all traversed lines.

The more efficient turbulence model in the present study is the SST model which gives nearly approaching results with the experimental measurements.

A good agreement between experimental measurements and numerical calculations, it can rely more on theoretical solutions.

References

[1] L. Okushima, S. Sase and M. Nara, "A support system for natural ventilation design of greenhouses based on computational aerodynamics," Acta Horticulturae , vol. 284, p. 129–136, 1989.

[2] S. Sase and T. Takakura, "Wind tunnel testing on airflow and temperature distribution of a naturally ventilated greenhouse," Acta Horticulturae , vol. 148, p. 329–336, 1984.

[3] I. B. Lee and T. H. Short, "Verification of Computational Fluid Dynamic Temperature Simulations in A Full–Scale Naturally Ventilated Greenhouse," Transactions of the ASAE, vol. 44, no. 1, p. 119–127, 2000.

[4] J. B. Campen and G. P. A. Bot, "Determination of Greenhouse-specific Aspects of Ventilation using Three-dimensional Computational Fluid Dynamics," Biosystems Engineering , vol. 84 , no. 1, p. 69–77, 2003.

[5] T. Bartzanas, T. Boulard and C. Kittas, "Effect of vent arrangement on windward ventilation of a tunnel greenhouse," Biosystems Engineering, vol. 88, p. 479–490, 2004.

[6] V. J. Flores, J. I. Montero, E. J. Baeza and J. Lopez, "Mechanical and natural ventilation systems in a greenhouse designed using computational fluid dynamics," Int J Agric & Biol Eng, vol. 7, no. 1, p. 1 — 16, 2014.

ISSN 2601-8683 (Print)
ISSN 2601-8675 (Online)
European Journal of
Formal Sciences and Engineering
January - June 2020
Volume 3, Issue 1

Eigenfrequency and Euler's Critical Load Evaluation of Transversely Cracked Beams with a Linear Variation of Widths

Matjaž Skrinar

Department of Structural Mechanics Faculty of Civil Engineering, Transportation Engineering and Architecture University of Maribor

Abstract

For a truthful evaluation of the mechanical response of structures reliable and adequate computational models are essential. Consequently, various researches have been devoted to the mathematical representation of cracked structures. This paper studies the performance of the simplified crack model in estimations of fundamental eigenfrequency as well as elastic Euler's critical load for transversely cracked beams of rectangular cross-sections with linearly-varying widths. To obtain these solutions for different beams with diverse boundary conditions Rayleigh's energy method which requires an assumed transverse displacement function can be applied. After the appropriate displacement function is being selected, kinetic and strain energy, as well as the work done by an external axial compressive force P are evaluated. From these values, the estimations of the fundamental eigenfrequency, as well as the critical load, are assessed. To obtain these preliminary estimates, static deflection functions were applied initially. These functions represent a wide group of suitable functions since they automatically satisfy the required kinematic boundary conditions. Afterwards, alternative functions constructed from a dedicated polynomial solution were applied. Since this mathematical form offers straightforward integration, the genuinely applied displacement functions were further upgraded, separately for eigenfrequency as well as for critical load estimation. All obtained simplified model's solutions were afterwards compared to the results from equivalent and more detailed 3D finite models of the examined structures. The comparisons of the results demonstrated very fine agreements with the results from 3D FE models for all performed analyses. The considered simplified model thus clearly yields a suitable alternative in modelling of cracked beams with a linear variation of width in those situations, where cracks have to be considered within the analysis.

Keywords: Cracked beams with transverse cracks; linear cross-sections' variations; simplified computational model; transverse displacements- functions; fundamental eigenfrequency evaluation; Euler's critical load.

1. Introduction

Any degenerative effect in structures during the utilization alters their mechanical reaction by considerably decreasing the stiffness and potentially leading to their failure. Therefore, several studies consider the detection and identification of stiffness reductions in engineering structures. Such approaches for damages recognition and classification are often based on the measured structure's answer since the occurrence of damage changes the structures' response parameters. However, the efficiency of these strategies depends on the quality of measured data as well as on computational models implemented.

When analyzing cracked structures' response thorough meshes of 2D or 3D finite elements offer the finest description of a general structure, as well as of the cracks and their surroundings. Despite this, simplified models requiring fewer data are usually implemented in structural health monitoring techniques. The "discrete spring" model presented by Okamura et al. (Okamura et al., 1969) is the model that has been implemented in numerous research studies. Due to its simplicity this simplified model has been intensively applied in vibration analysis of cracked beams (F. Bakhtiari-Nejad et al., 2014), new various approaches for inverse identification of cracks (Labib et al., 2015), as well as in experimental inverse identifications of a crack (Cao et al., 2014) or a concentrated damage (Greco and Pau, 2011). Further, several papers were devoted to Euler–Bernoulli beam's finite element having an arbitrary number of transverse cracks differing in the principles of mechanics applied to obtain closed-form solutions of the genuine governing differential equation for transverse displacements (Biondi and Caddemi, 2007; Palmeri and Cicirello, 2011; Skrinar, 2009; Skrinar and Pliberšek, 2012).

The majority of the research has been limited to structural elements with constant rectangular cross-sections. Skrinar and Imamović (Skrinar and Imamović, 2018) studied bending of beams of various heights' variations along the length implementing a multi-stepped multi-cracked beam finite element (Skrinar, 2013) where the genuine continuous variation of height was modelled by an adequate series of steps. Although this model offers good (but approximate) results, it is limited to bending analyses only.

In this paper, the area of utilization of the simplified crack model is expanded to beams with linearly-varying widths where Rayleigh's energy method is being implemented for fundamental frequency and Euler's critical load estimations.

2. Simplified Computational Model

As a crack in a beam alters the local compliance, the crack is in Okamura "discrete spring" mathematical representation modelled as a massless rotational linear spring of appropriate stiffness. The neighbouring non-cracked parts of the beam to the left and to the right of the crack are modelled as elastic elements, connected by a linear spring. For the first definition for rotational spring's stiffness (given by Okamura et al. for a rectangular cross-section) as well as for all other definitions, the linear moment-rotation

constitutive law is adopted. The model thus allows for a rather effortlessness description of a crack as only two parameters are required: its location L_1 from the left end of the beam, and its depth which governs the spring stiffness K_r.

3 Implementation of Rayleigh's Energy Method for Fundamental Frequency and Euler's Critical Load Estimations

Structural analysis is mainly concerned with the determination of a physical structure's response when subjected to some action. Each new computational model's behaviour must be therefore tested in various engineering situations such as static, dynamic or buckling analyses.

In dynamic analysis, eigen or natural frequencies are one of the basic properties of elastic dynamic systems. Each such system has one or more natural frequencies i.e. frequency at which it tends to vibrate freely in the absence of any driving or damping force. Therefore, the simplified model's abilities in the first natural frequency prediction were studied as they dependent only on the structure's properties (its stiffness and participating mass) and not on the load function.

There are many available methods for determining the natural frequency (Newton's Law of Motion, Rayleigh's Method,...). Some of these methods yield a governing equation of motion (from which the natural frequency may be determined afterwards), and the others produce the natural frequency only.

In this study, which examines the behaviour of the simplified computational model, Rayleigh's method (also known as the energy method), which reduces the dynamic system to a single-degree-of-freedom system consequently yielding just the first natural frequency is being utilised.

Rayleigh's method requires an assumed displacement function $w(x)$. If this function is identical to the solution of the corresponding differential equation of motion (i.e. mode shape), the true fundamental frequency is being obtained. As this is seldom true, the assumed displacement function introduces additional constraints. Because they increase the stiffness of the system, Rayleigh's method overestimates the true fundamental frequency. The fundamental lemma of the method thus states that the total energy of the system is equal to the maximum kinetic energy which also equals the maximum deformation (potential) energy.

For the situation where the breathing of the crack is not considered i.e., the crack remains open, the "strain" energy (the potential energy stored as elastic deformation of the structure including crack) is approximated as:

$$U_{strain} = \frac{1}{2} \cdot \left(\int_{x=0}^{L_1} EI(x) \cdot (w_1''(x))^2 \cdot dx + \int_{x=L_1}^{L} EI(x) \cdot (w_2''(x))^2 \cdot dx + K_r \cdot (w_1'(L_1) - w_2'(L_1))^2 \right) \quad (1)$$

In Eq.(1) functions $w_1(x)$ and $w_2(x)$ are functions that represent the transverse displacements and must satisfy the most important kinematical boundary conditions, such as displacement and rotation. The more accurate displacement function also provides a more accurate result. In the absence of an exact solution of the differential equation (mode shape), approximate functions are applied, where static deflection functions $v(x)$ represent a wide group of suitable functions since they automatically satisfy the required kinematic boundary conditions.

To obtain the first eigenfrequency estimation the beam's kinetic energy is approximated as

$$U_{kin} = \frac{\omega_1^2}{2} \cdot \left(\int_{x=0}^{L_1} m(x) \cdot (w_1(x))^2 \cdot dx + \int_{x=L_1}^{L} m(x) \cdot (w_2(x))^2 \cdot dx \right) \tag{2}$$

implementing the same displacement functions.

Afterwards, the first in-plane vibrations eigenfrequency estimate is obtained from the total mechanical energy conservation law:

$$U_{strain} = U_{kin} \tag{3}$$

The results from these functions $w(x)$ can be improved by evaluating new upgraded displacement functions due to a transverse load, given as $q(x)=m(x)\cdot\omega^2\cdot w(x)$.

The strain energy approximation can be also applied in the energy method for the buckling load evaluation. The method assumes that the elastic system is a conservative system in which energy is not dissipated as heat, and, therefore, the energy added to the system by the applied external forces is stored in the system in the form of strain energy. The work (i.e. "applied" energy) done on the system by an external axial compressive force P is evaluated by applying the same transverse displacements functions:

$$U_{app} = \frac{P}{2} \cdot \left(\int_{x=0}^{L_1} (w_1'(x))^2 \cdot dx + \int_{x=L_1}^{L} (w_2'(x))^2 \cdot dx \right) \tag{4}$$

The energy conservation law states:

$$U_{strain} = U_{app} \tag{5}$$

from which the estimate of the buckling load P_{crit} can be evaluated.

Therefore, although the same static transverse displacements function due to bending allow for a very straightforward implementation either in natural frequency as well as in buckling analysis, their solutions are not the finest.

Therefore, the assumed displacement functions $w(x)$ are usually constructed from the analysed problem's dedicated polynomial solution, primarily due to ease of their integration which is essential for a successful subsequent upgrade of the solutions.

Among the results obtained by implementing various assumed displacement functions, the smallest value yields an upper limit of the true fundamental frequency or buckling load.

4. Numerical Validations

Four cracked fundamental beam-structures were analyzed in order to investigate the effectiveness of the simplified model. For all four structures that differed only in boundary conditions, the length L was 10 m and the Young modulus was 30 GPa with Poisson's ratio 0.3. The cross-section was a rectangle with height h = 0.2 m where the width b was linearly increasing from 0.1 m at the left-end to 0.2 m at the right-end. A single transverse crack of the depth of 0.1 m was located at the mid-span to maximise its impact on the results for the majority of the examples, and the rotational spring's definition given by Okamura was selected.

The obtained results were further compared with the values from a commercial finite element program COSMOS/M where corresponding 3D finite models of the considered structures were established and analyzed. The computational model consisted of 48,000 3D solid finite elements with almost 75,000 nodal points. In each node, three degrees of freedom were taken into account – vertical and two horizontal displacements. The model's vertical and horizontal displacements were obtained in discrete points by solving more than 220,000 linear equations. Since this model allows for a realistic description of the crack those results further served as the reference values.

In the first phase, the first eigenfrequency and the buckling load estimations were obtained by implementing static deflection functions due to a downward vertical uniform load q=2000 N/m along the complete structure. These functions were further introduced into Eqs.(1)-(5).

Afterwards, basic polynomial functions were constructed for each of the considered structures considering general boundary conditions only. The implementation of these functions in Eqs.(1)-(5) yielded new sets of results for the first eigenfrequency and the buckling load.

These basic general polynomial functions were also upgraded accordingly to the specific problem to see the impact of functions' improvement to the quality of the results for both studied problems.

In the penultimate step, special polynomial functions devoted exclusively to buckling analyses were created by considering additional boundary data. Ultimately, also these functions were upgraded.

4.1 Simply Supported Beam

Initially, the governing differential equation of the elastic line for a slender beam subjected to bending in the plane of symmetry was solved. This equation, known also as Euler–Bernoulli equation of bending, relates transverse displacement $v(x)$, the

coordinate *x*, the geometrical and mechanical properties of the cross-section (unified in flexural rigidity *EI(x)*), and the applied transverse load *q(x).* For the case considered where the flexural rigidity *EI(x)* is not a constant value this relation yields a fourth-order ordinary differential-equation with non-constant coefficients. However, the crack, located arbitrarily within the beam ($0 \le L_1 \le L$), separates the beam into two elastic parts, and to obtain the transverse displacements two coupled differential equations had to be solved. Consequently, two displacement functions for the parts on the left ($v_1(x)$) and right ($v_2(x)$) side of the crack were obtained:

$$v_1(x) = 145.087 + 15.476 \cdot x + 0.05 \cdot x^2 - 8.333 \cdot 10^{-4} \cdot x^3 - 10 \cdot \mathrm{Ln}\left(2 \cdot 10^6 + 200000 \cdot x\right) - x \cdot \mathrm{Ln}\left(2 \cdot 10^6 + 200000 \cdot x\right) \qquad 0\,\mathrm{m} \le x \le 5\,\mathrm{m}$$

$$v_2(x) = 145.060 + 15.481 \cdot x + 0.05 \cdot x^2 - 8.333 \cdot 10^{-4} \cdot x^3 - 10 \cdot \mathrm{Ln}\left(2 \cdot 10^6 + 200000 \cdot x\right) - x \cdot \mathrm{Ln}\left(2 \cdot 10^6 + 200000 \cdot x\right) \qquad 5\,\mathrm{m} \le x \le 10\,\mathrm{m}$$

The quality of these solutions was verified by analysing the considered structure by implementing the COSMOS/M commercial finite element program. This model produced the midpoint's vertical displacement of -0.1009 m thus confirming excellent result from the simplified model which has produced the value of -0.1013 m (with 0.34 % discrepancy). Matching of the results between the two models was also very good for all other points along the beam as the discrepancy nowhere exceeded the value at the crack location.

The initial eigenfrequency estimation was generated by inserting bending solutions into Eqs.(1)-(3). This resulted in the value ω_1 = 18.53651 rad/s for the first eigenfrequency estimation. On the other hand, the 3D FE model produced the value of 18.53429 rad/s again confirming excellent quality of the result from the simplified model as the discrepancy between the two models' results was very low (0.01198 %).

Afterwards, also the buckling load P_{crit} was approximated from Eqs. (4)-(5) by implementing the same transverse displacements functions. The buckling load estimation was 258,229 N. Alternatively, the 3D FE model produced the value of 256,693 N thus showing that the simplified model produced the results with a moderately small discrepancy (0.5985 %).

Afterwards, general basic polynomial functions $w_1(x)$ and $w_2(x)$ were constructed by considering specific boundary conditions only (implementing zero boundary displacements as well as bending moments):

$$w_1(x) = 0.339 \cdot x - 8.328 \cdot 10^{-3} \cdot x^3 + 5.552 \cdot 10^{-4} \cdot x^4 \qquad 0\,\mathrm{m} \le x \le 5\,\mathrm{m}$$

$$w_2(x) = -8.194 \cdot 10^{-2} + 0.563 \cdot x - 8.328 \cdot 10^{-2} \cdot x^2 + 2.776 \cdot 10^{-3} \cdot x^3 \qquad 5\,\mathrm{m} \le x \le 10\,\mathrm{m}$$

The implementation of these functions into eigenfrequency computation resulted in the value of ω_1 = 18.6983 rad/s for the first eigenfrequency estimation which is clearly an

inferior result to the value from the bending functions as discrepancy increased to a (still quite acceptable) value of 0.885 %.

The same basic polynomial displacement functions were further implemented in the buckling load analysis already producing an acceptable value for the buckling load: 259,238 N with a discrepancy of almost 1 % (which was again higher than at static bending functions' utilisation).

Since the displacement functions were simple polynomials, the upgrading of basic polynomial functions was afterwards separately performed for first eigenfrequency estimation as well as for buckling estimation without any mathematical issues, yielding the following functions:

$$w_{d,1}(x) = -0.204\cdot\omega^2 - 2.838\cdot10^{-2}\cdot\omega^2\cdot x - 4.436\cdot10^{-4}\cdot\omega^2\cdot x^2 - 3.777\cdot10^{-6}\cdot\omega^2\cdot x^3 + 1.889\cdot10^{-7}\cdot\omega^2\cdot x^4$$
$$+ 5.925\cdot10^{-8}\cdot\omega^2\cdot x^5 - 1.597\cdot10^{-9}\cdot\omega^2\cdot x^6 - 1.338\cdot10^{-10}\cdot\omega^2\cdot x^7 + 5.901\cdot10^{-12}\cdot\omega^2\cdot x^8$$
$$+ 8.873\cdot10^{-3}\cdot\omega^2\cdot(10+x)\cdot\mathrm{Ln}(10+x) \qquad 0\,\mathrm{m} \le x \le 5\,\mathrm{m}$$

$$w_{d,2}(x) = 0.188\cdot\omega^2 + 2.7554\cdot10^{-2}\cdot\omega^2\cdot x + 4.192\cdot10^{-4}\cdot\omega^2\cdot x^2 - 3.419\cdot10^{-5}\cdot\omega^2\cdot x^3 + 1.624\cdot10^{-6}\cdot\omega^2\cdot x^4$$
$$+ 1.820\cdot10^{-8}\cdot\omega^2\cdot x^5 - 3.084\cdot10^{-9}\cdot\omega^2\cdot x^6 + 5.508\cdot10^{-11}\cdot\omega^2\cdot x^7$$
$$- 8.122\cdot10^{-3}\cdot\omega^2\cdot(10+x)\cdot\mathrm{Ln}(10+x) \qquad 5\,\mathrm{m} \le x \le 10\,\mathrm{m}$$

The newly derived at upgraded polynomial approximations $w_d(x)$ (obtained through four consecutive integrations of genuine basic polynomial functions) for the first eigenfrequency estimation produced the value ω_1 = 18.51594 rad/s, which has a rather low discrepancy (-0.099 %) against the 3D model value. However, it should be noted that the obtained value underestimated the value from the 3D model which is not consistent with the theory. Nevertheless, this divergence was a consequence of the computational model and not of the method, as the approximate method is being applied to a simplified model. It should be also noted that the upgrading process could have been further repeated. However, this was not executed due to the already low discrepancy achieved.

The separate upgrade of original polynomial function was executed also for the buckling problem. A new set of transverse displacements functions were derived at by realising that in buckling the transverse displacements are a sole function of axial compressive force P_{crit}. Therefore, the bending moments' functions were expressed as functions of applied axial force and transverse displacements. The considered problem's specific relation was $M_z(x) = -P_{crit}\,v(x)$. After two consecutive integrations the following functions were obtained:

$$w_{b,1}(x) = 1.208\cdot10^{-3}\cdot P_{crit} + 1.745\cdot10^{-4}\cdot P_{crit}\cdot x + 2.623\cdot10^{-6}\cdot P_{crit}\cdot x^2 - 1.157\cdot10^{-7}\cdot P_{crit}\cdot x^3 + 5.783\cdot10^{-9}\cdot P_{crit}\cdot x^4$$
$$- 1.388\cdot10^{-10}\cdot P_{crit}\cdot x^5 - 5.246\cdot10^{-5}\cdot P_{crit}\cdot(10+x)\cdot\mathrm{Ln}(10+x) \qquad 0\,\mathrm{m} \le x \le 5\,\mathrm{m}$$

$$w_{b,2}(x) = -1.934\cdot10^{-3}\cdot P_{crit} - 2.766\cdot10^{-4}\cdot P_{crit}\cdot x - 4.1845\cdot10^{-6}\cdot P_{crit}\cdot x^2 + 9.253\cdot10^{-8}\cdot P_{crit}\cdot x^3 - 1.157\cdot10^{-9}\cdot P_{crit}\cdot x^4$$
$$+ 8.410\cdot10^{-5}\cdot P_{crit}\cdot(10+x)\cdot\mathrm{Ln}(10+x) \qquad 5\,\mathrm{m} \le x \le 10\,\mathrm{m}$$

With these two new functions the "strain" energy, Eq.(1), as well as the "applied" energy, Eq.(4), were re-evaluated. Finally, Eq.(5) yielded the improved value for the buckling load of P_{crit} = 257,606.5 N with a decreased discrepancy of 0.356 %.

In the last part, special alternative functions constructed from a dedicated polynomial solution were applied exclusively for the buckling analysis. These functions were constructed by additionally considering boundary information regarding shear forces which resulted in the unknown buckling load P_{crit} to be included in the displacement functions $w_s(x)$ (due to their complexity these functions are not presented here). The buckling load obtained from these functions was 258,346.2 N (with the discrepancy of 0.644 %). These functions produced the result which was better than the value obtained from the original basic general polynomial function, but worse from those from the improved general polynomial solution. Consequently, it was expected that the upgrading of these dedicated functions will result in the best approximation. However, the integration of these functions (that included the unknown buckling load P_{crit}) initially failed. Therefore, in the integrations within the upgrade process, the value of the unknown buckling load was taken as 258,346.2 N. Consequently, the bending functions become simple polynomials which allowed the integrations to be completed resulting in functions $w_{su}(x)$. The obtained buckling load was 257,557.4 N which became the simplified model's best results as the discrepancy was 0.3369 % (which is just slightly better than the value that resulted from the upgrading of basic general polynomials).

Afterwards, the above-described analyses were repeated for several locations of the crack along the beam, and the essential results are given in Tables 1 and 2.

It is obvious from Table 1 that almost all the simplified model's solution overestimate the corresponding "exact" values (i.e. values from the 3D FE model) as there are just two cases where the results just slightly underestimate the values from the 3D FE model. Initial simple general polynomial solutions $w(x)$ mostly provided the least accurate results. However, these functions allowed for upgrading ($w_d(x)$) that provided the situation's lowest values that, according to the theory, should also be the most accurate.

Similarly, Table 2 apparently shows that all the simplified model's solutions overestimate the corresponding values from the 3D FE model also in buckling analyses. Basic general polynomial solutions $w(x)$ initially provided results with less accuracy than the static bending displacement functions $v(x)$ for almost all locations. However, general polynomial solutions also allowed for the upgrade ($w_b(x)$) that in most case further produces slightly better results than the static bending displacement functions.

Furthermore, original special polynomial approximations $w_s(x)$ performed somehow better than general basic approximations. Ultimately, the best results for almost all locations were obtained from the upgrades ($w_{su}(x)$) of these special dedicated polynomials. The only exception is the case where the crack was 1 m from the weaker part of the structure where the static bending displacement functions produced just a slightly better result.

4.2 Cantilever, Clamped at the Right End

As the second structure, a cracked cantilever was examined. Again, derived at bending GDE's solutions $v(x)$ were compared against the 3D FE model solutions. The simplified model produced the free end's vertical displacement of -0.7272 m with a rather small discrepancy (0.032 %) against the 3D FE model result. However, it is interesting to note that the discrepancy at the crack location is slightly higher (0.142 %) as the discrepancy actually increased with the distance from the free end. Nevertheless, the general matching of the results between the two models was actually very good for all the points along the cantilever as the maximum discrepancy was everywhere below 1 %. After the verification of the simplified model's displacement functions, the initial eigenfrequency, as well as buckling load values were calculated and compared to the matching values from the 3D FE model. All these values are given in Tables 3 and 4.

After that, general basic polynomial functions $w(x)$ were constructed by considering example's specific boundary conditions only (considering zero boundary displacement and rotation as well as bending moment). These functions, as well as their upgrades ($w_d(x)$ and $w_b(x)$), produced new values of the fundamental eigenfrequency and buckling load (see Tables 3 and 4).

The cantilever's study was completed by obtaining a buckling analysis dedicated polynomial solutions $w_s(x)$. These functions were constructed by considering additional boundary information regarding shear forces at the clamped end. In contrast to the simply supported beam structure, the inclusion of this additional information did not result in the unknown buckling load to be included in the newly derived at displacement functions. Consequently, the integration of these functions ($w_{su}(x)$) in the upgrading process did not cause any numerical problems. Both obtained values for the fundamental buckling load are given in Table 4.

It is evident from Tables 3 and 4 that static bending functions $v(x)$ produced a very decent result in the fundamental eigenfrequency estimation and, on the other hand, were quite unsuccessful in the buckling load analysis. Similarly, also general basic polynomials $w(x)$ performed well in dynamic analysis and were slightly less efficient in Euler load evaluation. Nevertheless, separate upgrades of basic polynomial approximations for both kinds of problems brought evident improvement of the results where the results for eigenfrequency once more exhibited slightly better agreement with the results from the 3D FE model. However, the special polynomial approximations $w_s(x)$ for buckling analysis already initially provided a decent result which was further efficiently improved with the upgrade process.

4.3 Propped Cantilever

All the above-described procedures were also repeated for the third structure, a propped cantilever with clamped-simply supported boundary conditions. The main results are summarised in Tables 5 and 6.

4.4 Clamped-clamped Beam

As the last a clamped-clamped beam was examined. The key results from the procedures already explained above are given in Tables 7 and 8.

Conclusions

The fundamental eigenfrequency, as well as Euler's critical load determination for transversely-cracked slender beams with a linear variation of width, was studied by implementing the simplified Okamura's computational model of cracked beams. The solutions for four beam structures were obtained through Rayleigh's energy method where kinetic and strain energy, as well as the work done by an external axial compressive force P, were evaluated by applying appropriate transverse displacement functions. In the paper, various displacements functions were applied. The results obtained with the implementation of the simplified model with the combination of various functions were afterwards compared to the results obtained from the pure numerical approach implementing 3D finite elements within the framework of the finite element method.

Initially, transverse displacements' functions $v(x)$ due to transverse load were implemented. Although they produced good values for the first eigenfrequency (with the discrepancy below 0.4 %) the quality of the results for the buckling load was not very consistent as for some cases they have produced very low discrepancies (0.6 %), but for some other examples, the discrepancy was evidently higher (up to 18 %). Furthermore, since these functions are not given as plain polynomials their upgrade through their integrations was not possible. Afterwards, alternative general polynomial functions $w(x)$ were constructed. Also these functions exhibited better results for eigenfrequency estimations. The maximum discrepancies were namely up to 3.8 % for eigenfrequency analysis and up to 10.8 % for buckling load analysis. However, their mathematical form allowed for integration and, therefore, the genuine polynomial functions were further upgraded, separately for eigenfrequency ($w_d(x)$) as well as for critical load ($w_b(x)$) estimation. These separated upgrades for eigenfrequency and buckling analyses have evidently improved the quality of the results. The discrepancies in eigenfrequency analysis almost vanished (below 0.1 %) while the discrepancies for the buckling load dropped below 1.5 %.

In the end, special polynomial functions $w_s(x)$ were constructed just for buckling analyses producing evidently better results than the general polynomial functions $w(x)$ with the maximum discrepancy around 2.1 %. These functions have been further upgraded. Although these improved functions ($w_{su}(x)$) generally produced the best results their improvement was not as apparent as in the previous cases as their discrepancies were already rather low prior to upgrading.

Despite the clear differences in the mathematical form and computational efforts between both computational models considered, the considered examples have thus

shown that the application of the simplified model produces adequately matching of the results as no major differences are noticeable against 3D FE solutions. It can be thus concluded that the model is suitable for free vibration analyses with non-breathing crack as well as for buckling load evaluation. It is even reasonable to assume that by applying appropriate transverse displacement functions even higher eigenfrequencies could be evaluated.

The Okamura's computational model has thus proved itself to be usable for beams with linear variations of widths even by applying rather simple analysis methods. Nevertheless, it is rational to expect that by implementing more dedicated computational methods for eigenfrequency analysis as well as for buckling analysis this would also reflect in better results from the simplified model.

Acknowledgements

The author acknowledges the partial financial support from the Slovenian Research Agency (research core funding No. P2-0129 (A)).

References

[1] Bakhtiari-Nejad, F., Khorram, A., Rezaeian, M. (2014). Analytical estimation of natural frequencies and mode shapes of a beam having two cracks. *International Journal of Mechanical Sciences, 78*, 193–202.

[2] Biondi, B., Caddemi, S. (2007). Euler-Bernoulli beams with multiple singularities in the flexural stiffness". *European Journal of Mechanics - A/Solids, 26*(5), 789-809.

[3] Cao, M., Radzieński, M., Xu, W., Ostachowicz, W. (2014). Identification of multiple damage in beams based on robust curvature mode shapes. *Mechanical Systems and Signal Processing, 46*, 468–480.

[4] Greco, A, Pau, A. (2011). Detection of a concentrated damage in a parabolic arch by measured static displacements. *Structural Engineering & Mechanics, 39*(6), 751-765.

[5] Labib, A., Kennedy, D., Featherston, C. A. (2015). Crack localisation in frames using natural frequency degradations. *Computers and Structures, 157*, 51–59.

[6] Okamura, H., Liu, H.W., Chorng-Shin, C. (1969). A cracked column under compression. *Engineering Fracture Mechanics, 1*(3), 547-564.

[7] Palmeri, A., Cicirello, A. (2011). Physically-based Dirac's delta functions in the static analysis of multi-cracked Euler-Bernoulli and Timoshenko beams. *International Journal of Solids and Structures*, *48*(14-15), 2184-2195.

[8] Skrinar, M. (2009). Elastic beam finite element with an arbitrary number of transverse cracks. *Finite Elements in Analysis and Design, 45*(3), 181-189.

[9] Skrinar, M., Pliberšek, T. (2012). On the derivation of symbolic form of stiffness matrix and load vector of a beam with an arbitrary number of transverse cracks. *Computational material science, 52*(1), 253-260.

[10] Skrinar, M. (2013). Computational analysis of multi-stepped beams and beams with linearly-varying heights implementing closed-form finite element formulation for multi-cracked beam elements. *International Journal of Solids and Structures, 50*(14/15), 2527-2541.

[11] Skrinar, M., Imamovic, D. (2018). On the Bending Analysis of Multi-Cracked Slender Beams with Continuous Height Variations. *Periodica Polytechnica Civil Engineering*, *62*(4), 873-880. https://doi.org/10.3311/PPci.11897

Table 1: Results for fundamental eigenfrequency ω_1 [rad/s] for the simply supported beam

	Functions/model			
L1	v(x)	w(x)	wd(x)	3D FE
1 m	19.52986	22.49288	19.51193	19.48735
2 m	19.19155	20.77441	19.17580	19.14632
3 m	18.83349	19.65291	18.81885	18.78653
4 m	18.59319	18.99199	18.57628	18.58736
5 m	18.53651	18.69833	18.51594	18.53429
6 m	18.67056	18.70218	18.64743	18.62232
7 m	18.95363	18.93382	18.93022	18.91004
8 m	19.29570	19.29387	19.27301	19.25661
9 m	19.57118	19.62610	19.54853	19.53399

Table 2: Results for buckling load P_{crit} [N] for the simply supported beam

	Functions/model					
L_1	*v(x)*	*w(x)*	$w_b(x)$	$w_s(x)$	$w_{su}(x)$	3D FE
1 m	285104.3	339121.8	287056.7	308723.4	285468.7	283826.0
2 m	273286.9	294491.2	273529.8	282226.0	272810.7	271407.9
3 m	263088.2	271730.4	262402.4	266115.2	262117.1	260947.2
4 m	257902.7	261355.8	257111.3	258784.3	256987.0	255966.7
5 m	258229.1	259237.6	257606.5	258346.2	257557.4	256692.7
6 m	263352.1	263245.0	262925.0	263204.4	262921.3	262201.6
7 m	271791.8	271816.4	271538.2	271615.0	271524.6	270944.1
8 m	281167.4	282875.9	281011.4	281076.4	280880.7	280389.8
9 m	288346.3	292723.4	288132.0	288365.6	287851.1	287389.3

Table 3: Results for the fundamental eigenfrequency ω_1 [rad/s] of the cantilever

Method/model	ω_1	discrepancy
COSMOS 3D FE model	8.494559 rad/s	-
bending functions *v(x)*	8.519639 rad/s	0.295 %
general basic polynomial approximations *w(x)*	8.529249 rad/s	0.408 %
upgrade of general polynomial approximations $w_d(x)$	8.492690 rad/s	-0.022 %

Table 4: Results for buckling load P_{crit} [N] of the cantilever

Method/model	P_{crit}	discrepancy
COSMOS 3D FE model	76724.8 N	-
bending functions *v(x)*	90559.3 N	18.031 %
general basic polynomial approximations *w(x)*	81818.4 N	6.639 %
upgrade of basic polynomial approximations $w_b(x)$	76856.7 N	0.172 %
special polynomial approximations $w_s(x)$	78086.7 N	1.775 %
upgrade of special polynomial approximations $w_{su}(x)$	76809.6 N	0.110 %

Table 5: Results for the fundamental eigenfrequency ω_1 [rad/s] of the propped cantilever

Method/model	ω1	discrepancy
COSMOS 3D FE model	27.95442 rad/s	-
bending functions v(x)	28.02343 rad/s	0.247 %
general basic polynomial approximations w(x)	29.02114 rad/s	3.816 %
upgrade of general polynomial approximations wd(x)	27.94767 rad/s	-0.024 %

Table 6: Results for buckling load P_{crit} [N] of the propped cantilever

Method/model	P_{crit}	discrepancy
COSMOS 3D FE model	530869.9 N	-
bending functions *v(x)*	548504.2 N	3.322 %
general basic polynomial approximations *w(x)*	588154.4 N	10.791 %
upgrade of basic polynomial approximations $w_b(x)$	537350.8 N	1.221 %
special polynomial approximations $w_s(x)$	542066.3 N	2.109 %
upgrade of special polynomial approximations $w_{su}(x)$	533636.5 N	0.521 %

Table 7: Results for the fundamental eigenfrequency ω_1 [rad/s] of the clamped-clamped beam

method	ω_1	discrepancy
COSMOS 3D FE model	42.56036 rad/s	-
bending functions $v(x)$	42.72411 rad/s	0.385 %
general basic polynomial approximations $w(x)$	43.54528 rad/s	2.314 %
upgrade of general polynomial approximations $w_d(x)$	42.56100 rad/s	0.0015 %

Table 8: Results for buckling load P_{crit} [N] of the clamped – clamped beam

method	P_{crit}	discrepancy
COSMOS 3D FE model	1044774.0 N	-
bending functions $v(x)$	1101546.7 N	5.434 %
general basic polynomial approximations $w(x)$	1082479.2 N	3.609 %
upgrade of basic polynomial approximations $w_b(x)$	1030595.4 N	-1.357 %
special polynomial approximations $w_s(x)$	1052194.1 N	0.710 %
upgrade of special polynomial approximations $w_{su}(x)$	1028921.5 N	-1.517 %

ISSN 2601-8683 (Print)
ISSN 2601-8675 (Online)
European Journal of
Formal Sciences and Engineering
January - June 2020
Volume 3, Issue 1

Effect of Waterproofing Materials on Self-Healing Concrete

Tayfun Uygunoğlu

Afyon Kocatepe University, Engineering Faculty,

Civil Engineering Department

İlker Bekir Topçu

Eskişehir Osmangazi University, Faculty of Engineering and

Architecture, Civil Engineering Department

Abstract

Improving the strength of the concrete structures and increasing the service life is an important issue. The service times of the concrete remained; external factors such as water penetrating into these micro-cracks and shorten the life of the concrete. In order to solve this problem, the idea of self-healing concrete with bacteria or other materials has been put forward and studies have shown that using CaO based materials that repair cracks in this direction by precipitating calcite. It is obvious that long-term performance of concrete will increase with to prevent water pass to concrete interior. Instead of forming a barrier on the positive or negative side of concrete, waterproofing admixture turn the concrete itself into a water barrier. Internal concrete waterproofing systems can be water repellents or crystalline admixtures. In this study, waterproofing admixture was added to concrete mixture as waterproofing material and its effect on self-healing in terms of filling the pores was investigated. Beam samples including the CaO based waterproofing powder materials were produced in size of 285x75x25 mm. The samples were cracked in the flexural machine. After some days, the cracks were investigated by microscope. Crak control was continued till 28 days. At the end of study, the cracks smaller than 0.3 mm were self-healed. However, the bigger cracks than 0.3 mm cannot be self-healed by waterproofing material. Consequently, self-healing of concrete with CaO based waterproofing powder material is very promising for the environmentally friendly and sustainable structures of the future.

Keywords: Self-healing concrete, CaO based material, micro cracks, concrete repair

Introduction

During the service life of concrete structures, internal and external effects and micro-cracks occur in the structure. These cracks cause leakage of harmful substances into the concrete, deterioration of the strength and durability properties of the concrete, structural damages and crashes, and the high cost of maintenance and repair of the concrete structure. It is known that water-dissolved CO_2 reacts with Ca^{+2} ions in the concrete and can repair the concrete by forming $CaCO_3$ (limestone) crystals with very little water solubility. However, for this type of self-repair to occur, there must be water in the environment and this repair can only be made if the cracks are too small. Recently, bacterial concrete methods which has ability to self-healing are used to overcome maintenance and repair costs. In 1994, the first study on the ability to self-healing with the extra materials that were added to the concrete during the production of concrete was published by Carolyn Dry of Illinois University. Eric Schlagen and Henk Jonkers who have been researching about self-healing concrete by adding bacterial spores and calcium lactate foods to the mixture while producing concrete have made a remarkable study in this field since 2006. Bacterial concrete, Bacillus bacterial spores in the medium of the water-activated nutrients and calcium sources in the range of appropriate pH values in the concrete due to the formation of a fibrous structure is caused by precipitation of calcite. Thus, with the precipitation of calcite, the bacteria are embedded in concrete and the concrete is provided to improve itself.

Occurring mechanism of cracks which are inevitably in concrete due to its relatively lower tensile strength and action of different load and non-load factors may be varied including plastic shrinkage, drying shrinkage, thermal stresses, external loading and rebar corrosion or coupled effect of multiple factors (Souradeep et al. 2017). These cracks cause leakage of harmful substances into the concrete, deterioration of the strength and durability properties of the concrete, structural damages and crashes, and the high cost of maintenance and repair of the concrete structure. When growth of micro-cracks reaches from the surface of concrete to the reinforcement, corrosion occurs on reinforcement due to attack of aggressive agents (water, oxygen, CO_2, chlorides, etc.) which corrodes the reinforcement reducing its service life. The rate of aggressive agents' ingress into concrete is primarily dependent on the internal pore structure of concrete (Vijay et al. 2017). Therefore, it is more important to prevent these cracks at the start or it will become a major crack, however, to repair this crack is not an easy task so some alteration is needed in the construction material (Kulthe et al. 2018).

In 1994, C. Dry was the first who proposed the intentional introduction of self-healing properties in concrete (Van Tittelboom and De Belie 2013). In recent years, there are many alternative repair mechanisms and one of them is based on the application of crystallation in concrete.

Theory

Application of traditional crack repairing systems usually contains applying a cementitious material-based mortar bonded to the damaged surface, which can be especially time consuming and expensive in concrete structures due to mostly difficult to get access to repair cracks (Rao et al. 2013). Biotechnology and nanotechnology are used to improve the properties of concrete. Consequently, bacteria-based concrete has been suggested as an alternative and sustainable crack repair technique. The conceptual idea provided by bacterial crack healing mechanism is that the bacteria should able to transform soluble organic nutrients into insoluble inorganic calcite crystals which seals the cracks (Rao et al. 2013). Concrete has a rather aggressive medium due to its high internal pH, relative dryness and lack of nutrients for common bacteria needed for growth, however, some extremophilic spore forming bacteria can survive in this medium and increase the strength and durability of concrete (Rao et al. 2013). But, the bacteria will not survive once the cells become jammed by $CaCO_3$ crystals and the bacterial activity will also come to an end once all nutrients are consumed. Therefore, it can be concluded that even the bacterial approach will not allow an endless repetition of the healing process (Van Tittelboom and De Belie 2013).

Concrete durability and permeability has a strong relationship. Bacteria-based concrete biologically produces calcium carbonate crystals to seal cracks. Calcium carbonate ($CaCO_3$) that is a common substance found in rocks exists in environments such as marine water, fresh water, and soils. There are many techniques to heal properties of concrete, among these techniques' bacteria-based concrete that special strains of bacteria capable of precipitating certain chemicals are used is a relatively new technique. According to Rao et al. (2013), autogenous healing occurs because of hydration of non-reacted cement particles present in the concrete matrix once meet leakage water resulting in in closure of micro cracks, however, due to the variability of autonomous crack healing of concrete micro cracks can still occur. The bacteria used in concrete should be able to have long-term effective crack sealing mechanism during its lifetime serviceability. Recent researches about bacteria-based concrete focus to heal cracks induced after 28-days of casting, which can be mentioned as an early age application for bacteria-based concrete (Bundur and Amiri 2016).

The mechanisms of microbially induced calcium carbonate precipitation (MICCP) can be achieved through different pathways like urea decomposition, oxidation of organic acids (aerobic process), or nitrate reduction (anaerobic process). Therefore, the effects of bacteria on concrete strength are variable. The precipitation rate of biological calcium carbonate is ideally influenced by concentration of calcium ions, pH of the solution, concentration of dissolved inorganic carbon and availability of nucleation sites. Alkali tolerant ureolytic strains, such as Sporosarcina pasteurii (Bacillus pasteurii), Sporosarcina ureae, Bacillus sphaericus, and Bacillus megaterium, that can decompose urea into ammonium/ammonia and carbonate ions (Equation 1) are the most commonly used bacteria in bacteria-based concrete. Bacterial urea hydrolysis requires oxygen to

initiate bacterial activity (spore germination), which can be a restricting factor for deep crack healing. Nitrate reduction by different strains, such as Diaphorobacter nitroreducens, under oxygen limited conditions, denitrifiers use nitrate (NO_3^-) to generate CO_3^{2-} and HCO_3^- ions, which are necessary for $CaCO_3$ precipitation (Equation 2). The alkaliphilic strains, such as Bacillus cohnii, Bacillus pseudofirmus and Bacillus alkalinitrilicus, which can degrade organic compounds into CO_2 and H_2O, and CO_2 can be easily converted to CO_3^{2-}, and with the presence of Ca^{2+}, $CaCO_3$ can be formed (Equation 3).

$$Ca^{2+} + CO_3^{2-} \longrightarrow CaCO_3 \quad (1)$$

$$Ca(C_3H_5O_3) + 6O_2 \longrightarrow CaCO_3 + 5CO_2 + 5H_2O \quad (2)$$

$$5CO_2 + 5Ca(OH)_2 \longrightarrow 5CaCO_3 + 5H_2O \quad (3)$$

There are some basic approaches for crack healing with bacteria: direct addition of bacteria into the fresh concrete; additions in the form of spores, immobilized form onto silica gel or activated carbon, encapsulated form, or using the vascular networks (Talaiekhozan et al. 2014). Concerns about the viability of the endospores within the improper and high pH environment of cement-based materials have led researchers to suggest encapsulation for the endospores. The encapsulation methods consist of enclosing the endospores in a protective covering. Thus, some encapsulation methods such as encapsulation in porous solids, capsule based, vascular based have improved for protecting the bacteria form improper environment conditions. The most generally used method, due to its ease and low cost, is immobilization in lightweight aggregates.

The crack reparinig mechanism can be tough in concrete with crystalline water proffing material (CWPM). When the CWPM compared with water in the pores of concrete, it acts with water and produces CaO based crystalline hydration products (Fig. 1). The hydrated materials fill the pores and, they do not allow penetrating of water inside of concrete.

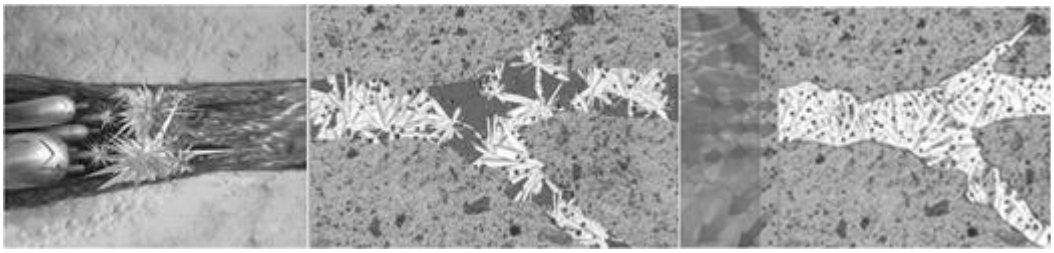


Figure 1. The crack filling mechanism of CWPM.

Therefore, the objective of this study is investigation of repairing effect of crystallation waterproofing materials as self-healing in concrete cracks. The crystalline products can be healed the crack of concrete (Van Tittelboom and De Belie 2013).

3. Experimental study

Plain control specimens and CWPM containing specimens in size of 285x75x25 mm were prepared and tested. Plain mortar specimens were used as reference. Plain control mixture was composed of river sand (1350 g), CEM I 42.5R cement (350 g) and, tap water (227,5 g). As repairing material, liquid CWPM and powder CWPM were used as 0%, 10%, 20% and 30% of cement dosage. Following demoulding, specimens were cured for one day at room temperature inside a tightly sealed bag. Cured specimens were cracked by applying flexural load with four point test. Multiple cracks were achieved in all mortar specimens (Fig. 2).

Figure 2. Small mortar beams for self-healing measurement

The obtained mulitple cracks were viewed under 1000X magnification microscope. The crack width measured and healing of cracks was investigated at 7 and 28 days aged samples. Also, water absorption test was carried out on the specimens.

Results and Discussion

Crystalline based powder and liquid material containing concrete cracks was experimentally conrolled by water absorption test. Almost, some cracks were checked for several days as self-healing. Fig. 3 shows the same crack with different magnification. It would be clearly seen that crack was filled with CWPM.

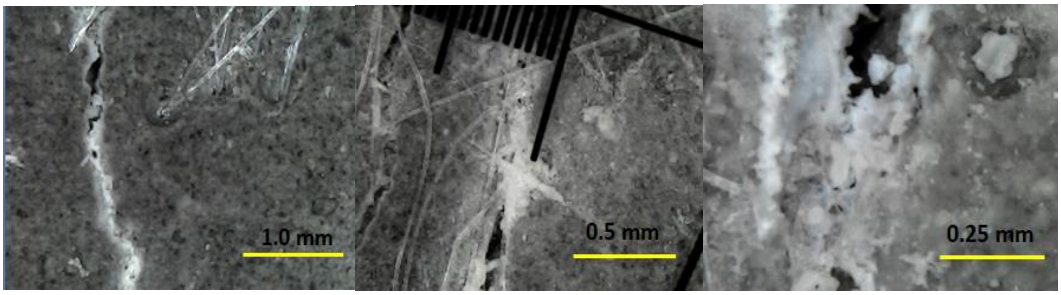


Figure 3. Crack filling with CWPM

Repairing of cracks in concrete structure occurs mostly early age, Souradeep et al. (2017) observed that bacteria repairs early age cracks more efficiently than later age cracks. Additionally, the crack healing ratio decreased remarkably along with the

increasing of cracking age (Lou et al. 2015). It was reported by Rao et al. (2013), life-time of bacteria added directly into concrete mixture is restricted due to continue cement hydration resulting in reduction of cement sand matrix pore-diameter. Moreover, for effective crack healing both bacteria and nutrients mixed into concrete should sustain to continue the integrity of concrete mixture (Rao et al. 2013). According to Vijay et al. (2017), it was observed that encapsulation method protects bacteria from improper environment of concrete so that self-healing efficiency about crack closer and the amount of calcium carbonate precipitation. Bundur and Amiri (2016) mentioned that the chemical admixtures studied herein have no significant influence over the performance of the MICCP applications in bacteria-based concrete. However, CWPM is cement based material, and it is not live. Therefore, it has not a life-time problem.

Many researches and Figure 2 support that cracks in bacteria-based concrete specimens fully filled with calcium carbonate provided by crack width up to 0.8 mm (Lou et al. 2015) or 100–200 μm (Souradeep et al. 2017), although it depends on several factors. When the average crack width increases, repairing of cracks are difficult and limited for bacteria repair agent (Figure 1b). To use crack area instead of crack width as measuring cracks was suggested by Souradeep et al. (2017).

To evaluate the crystalline waterproofing products efficiency, the most commonly used tests are those which measure water absorption and chloride penetration. Upon crack healing tests, cracks presented in Figure 4 were tested for water absorption. Water absorption through the healed cracks of specimens were less than the control specimens (Figure 4). As reported previously, CWPM self-healing of concrete cracks occurs at the crack mouth and provides a sealing effect. The absorption increase in the concrete with the liquid crystalline waterproofing admixture (in high volume, 30%) can be justified by a possible hygroscopicity generated by the use of this product may be a result of increase amount of evenly distributed small pores, or by the product may be hygroscopic and contribute to this increase absorption.

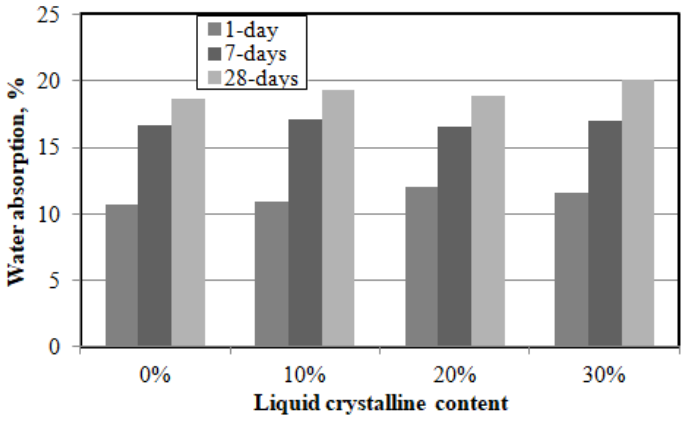


Figure 4. Water absortion of liquid CWPM containing samples

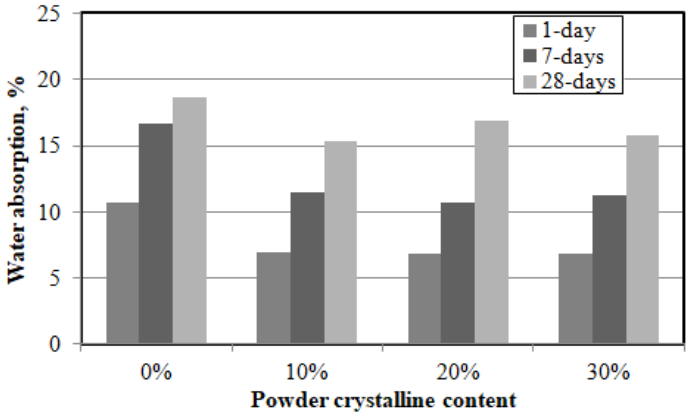


Figure 5. Water absortion of powder CWPM containing samples

It is observed that the use of powder crystalline waterproofing coating is more efficient compared with the concrete with liquid waterproofing admixture. The powder crystalline waterproofing coating system is a form of surface protection and has little dependence on the distribution of concrete voids, because it was expected to have better performance than the reference concrete. Thus, the powder crystalline waterproofing in most cases performed better than reference concrete. The crystalline waterproofing is to prevent the water penetration and allow the steam passage into the concrete (Capellesso, 2016).

Conclusion

This paper focused on ability of the healing of cracks in concrete with crystalline based materials. In the study, two types of crystalline cement based materials were used as self-healing in the concrete. The concrete samples were cracked after production, and they were cured till 28 days. The use of powder crystalline waterproofing material contributes filling of cracs that smaller than 0.8 mm, and it reduces the water absorption ratio. The use of powder waterproofing materials in 10% shows better self-healing and water absorption reducing performance than concretes which are including liquid waterproofing materials. If concretes are built with CWPM that is designed to perform under multiple damages, very low cost may be obtained over the life-time though initial cost may be higher than normal concrete. Also, we can obtain durable and sustainable concrete structures by their self-healing properties.

References

[1] Ali, A. H., Abo-El-Enein, S. A., Talkhan, F. N., Abdel-Gawwad, H. A. (2013). Application of microbial biocementation to improve the physico-mechanical properties of cement mortar. *HBRC Journal.* 9, 36-40.

[2] Bundur, Z. B., Amiri, A. (2016). Impact of Biogenic Self-Healing Additive on Performance of Cement-Based Mortar. *International RILEM Conference on Materials, Systems and Structures in Civil Engineering Conference segment on Service Life of Cement-Based Materials and Structures*, *22-24 August 2016, Technical University of Denmark, Lyngby, Denmark*, 492-502.

[3] Bundur, Z. B., Amiri, A., Azima, M. (2017). Bio-Based Admixture for Self-Healing Cement-Based Mortar. *2nd International Conference on Bio-based Building Materials & 1st Conference on ECOlogical valorisation of GRAnular and FIbrous materials*, *June 21th - 23th 2017, Clermont-Ferrand, France*, 91-95.

[4] Cappellesso VG, Petry NS, Molin DCCD, Masuero AB, (2016) Use of crystalline waterproofing to reduce capillary porosity in concrete*, J Build Rehabil (2016) 1:9*

[5] Kulthe, R., Mote, P., Kashid, S., Shinde, R. Kardile, N., Hinge, M. (2018). Bacteria Impregnated Concrete – A New Way to Increase the Durability of Concrete Structures. *International Journal of Advance Research in Science and Engineering,* 7(4), 341-346.

[6] Luo, M., Qian, C., Li, R. (2015). Factors affecting crack repairing capacity of bacteria-based self-healing concrete. *Construction and Building Materials*, 87, 1–7.

[7] Rao, M.V. S., Reddy, V. S., Hafsa, M., Veena, P., Anusha, P. (2013). Bioengineered Concrete - A Sustainable Self-Healing Construction Material. *Research Journal of Engineering Sciences*, 2(6), 45-51.

[8] Souradeep, G., Sze Dai, P., Wei, K. H. (2017). Autonomous healing in concrete by bio-based healing agents – A review. *Construction and Building Materials*, 146, 419–428.

[9] Talaiekhozan, A., Keyvanfar, A., Shafaghat, A., Andalib, R., Abd Majid, M.Z., Fulazzaky, M. A., Zin, R. M., Lee, C. T., Hussin, M. W., Hamzah, N., Marwar, N. F., Haidar, H.I. (2014). A Review of Self-healing Concrete Research Development. *Journal of Environmental Treatment Techniques.* 2(1), 1-11.

[10] Van Tittelboom, K., De Belie, N. (2013). Self-Healing in Cementitious Materials—A Review. *Materials*, 6(6), 2182-2217.

[11] Vijay, K., Murmu, M., Deo, S. V. (2017). Bacteria Based Self-Healing Concrete – A Review. Construction and Building Materials, 152, 1008–1014.

[12] Wiktor, V.A.C., Jonkers, H.M. (2012). Application of bacteria-based repair system to damaged concrete structures. 2nd international workshop on structural life management of underground structures, October 2012, Daejeon, South Korea, 31-34.

ISSN 2601-8683 (Print)
ISSN 2601-8675 (Online)
European Journal of
Formal Sciences and Engineering
January - June 2020
Volume 3, Issue 1

Electronic Signature and Electronic Contract, Comperative Aspect of Kosovo and Developed Countries

Islam Qerimi

MSc, Legal Consultat at Law Tech

Abstract

The study defines the advent of new technologies such as electronic contract and Electronic signature and other networks that have had impanct in changeing the business world wide and provided the trading processes in e-business more efficiency. In this article we will discuss about Electronic Constract and Electronic Signature in developed countries, how they have regulated this issue and when did it started to be used, wich do the positive and negative aspects, where Kosovo can benifite, know that in Kosovo is still not regulated with a law. We will focus on meeting the needs of the community in kosovo to have a law that Regulats the use of Electronic Contracts and Electronic Signature and trying to solve their problems in doing business world wide.

Keywords: Electronic Conctract, Electronic Signature, Eu-Directives, Kosovo and Developed Countries, Click Wrap, Brows Wrap.

Introduction

The Internet and digital technology are transforming our lives, everyday with the paces in a dimension of a real revolution. These fast and deep transformations are now being considered worldwide as the second most important revolution behind the industrial one. Using e-mail application for various services that different institutions and companies are offering to citizens enables lowering costs of printing, color, archiving requiring considerable space, and is also faster than service, and more quality.

While in terms of electronic contracts, they have managed to get a significant place in the development of legal relations between businesses, especially in electronic commerce, in many countries, the use of electronic contracts is increasing, but it is very important to deal in two aspects of electronic contracts, what are the advantages of its use, and what are the risks of electronic contracts, it is also important to address the characteristics of electronic contracts and what the factor is being made today in the development of business relations.

We will also address e-Governance, what it means, what is being practiced, and why it is important for a country as well as what is involved in e-governance, how are they approaching the digitalization trend, Kosovo and Albania. All of these will be dealt with based on our legislation, European Union directives, but special focus will be on the world practice of how are developing signatures, electronic contracts and e-governance, taking into accounts how they have found space worldwide in electronic contracts.

Methodology

The methodology used in the realization of this study is combined with the research, comparative, historical methods, although it is not the case that the electronic contract has a long history, but there is enough history, as well as methodical analysis or analytics, is used.

In this study we will refer to the facts collected from the materials prepared in recent years, from various laws, scientific papers, researches and various articles that have been made public, regarding the contract and the electronic signature, which is a very topic important to facilitate the development of international businesses.

Contract

The increasingly sophisticated economic relations, adapting to the time and technology that is becoming more useful everyday, has made the contract a vital asset for the development and advancement of businesses, seeing this development extremely fast, and with global proportions, different contracts have also emerged.

The main legal form in which economic work is performed are **contracts**. The great development of contemporary science and technology is also manifested in the ever-increasing number of contracts that should facilitate and simplify the relationship and realization of legal affairs (N.Dauti,2012)

The contract is a legal work for which the consent of the participating entities is required. As contract terms are:

- contracting ability;
- Reconciliation of will;
- Contracts;
- Legal basis of the contract (N.Dauti, 2012).

According to the Kosovo Law on Obligations, Article 16 states that "the contract is concluded when the contracting parties have agreed to the essential elements".

Field of Contract Implementation

The contract as a contracting form applies almost too all branches of law, except in criminal law. In the labor law, the contract finds expression in labor relations, as in

contracts between the employer and the employee, as well as in the collective labor contract. In economic law, contracts for the circulation of goods and the provision of services are mostly used. In financial law the contract applies to the arrangement of various financial transactions. Public international law through contract regulates relations between states. But it should be noted that the contract is mostly used in the right of obligations (N.Dauti, 2012).

Principle of contract freedom

The principle of contract freedom is an opportunity for the participants in the relationship of duty to regulate their mutual free will to regulate the mutual legal relations of the obligations. More specifically, the principle of freedom of contract means:

that every subject of the right freely choose to bind or not conclude the contract;

that every subject of the right freely chooses the person (partner) to whom he / she will sign the contract;

That the subjects of the right freely determine the content of the contract the form and manner of its attachment;

That the subjects of the right freely decide on the change and the ways of termination of the contract;

In case the contract is concluded between subjects with different citizenship, the subjects of the right can freely choose the legislation that will be applied in their contract (N.Dauti, 2012).

As can be seen above, we have a description of the main terms or principles of contract freedom, where these principles are the main basis of a contract and are vital to the implementation of a legal contract, these conditions protect both parties from eventual damage from the contract, and also gives you the freedom of contracting that is guaranteed by the applicable laws in the respective countries, these conditions are also essential for the electronic contract as the subjects themselves choose the way they want to enter into a contract or reach an agreement.

Restricting the freedom of contracting in view of the conclusion of the contract in general

Freedom of contracting is limited by the constitutional principles and the principles of the law itself, the cases of limiting the freedom of contracting:

Participants in the relationship of duty are free to regulate their relations according to their will, in accordance with the ordinance, public order and good doctrines.

Limitation of contractual freedoms through the legal obligation to enter into a contract (eg: car insurance contract, compulsory insurance of passengers, purchase of a border policy, etc).

Economic entities involved in hotel services should enter into a contract with persons who are directed to use their services (the hotel can not refuse the client for any serious reason other than objective reasons).

Restricting the freedom of contracting in view of the choice of the contracting party (if the subject which you have entered into a contract is a monopoly on the market, then we are dealing with limitation).

Restriction of contract freedom through pre-emption right (the seller of agricultural land is obliged to start offering it for purchase to the person who has the right of pre-emption and then others, this restriction has to do with regard to the choice of the contracting party)

Restricting the freedom of contracting can also be made in terms of the content of the contract, so that the contracting parties can not change anything (the contract on the loan is compiled by the bank, the interest rate is set, the contract content, and the borrower in this case has only possibility of selection, sign or not)

Restricting the freedom of contracting is also done through the contract of the contract where the content of the contract is compiled irrespective of the will of the parties (international oil sales, contract for postal services etc.)

Limiting the freedom of contracting through formwork contracts (contract for the sale of real estate, construction contract, deposit etc.)

Restricting the freedom of contracting through collective bargaining (all individual labor contracts must be in accordance with the collective bargaining agreement or not contain less favorable provisions for the contracting parties)

Restriction of contract freedom when the validity of the contract requires the granting of consent (the guardian gives consent that the care enters into contractual relations), (Granit Curri, 2015)

Expression of will - the will to conclude a contract can be expressed in different ways: in words, gestures, or other behaviors. Expression of will is expressly expressed and indirect will expressed. Indirect desire comes to the fore when a person with their behaviors implies that he wants to conclude a contract.

Negotiations - In many cases, the conclusion of a contract precedes the negotiations. Negotiations do not contain supply elements, so they do not have a binding character (Nerxhivane Dauti, 2004).

Time and place of conclusion of the contract - As the time of the conclusion of the contract is considered the moment when the bidder reaches the statement that the other party accepts the offer. As a place of contract award is considered the country in which the bid was made, respectively the place in which the bidder has the seat or the place in which the bidder had the place of residence at the time the bid was made.

Offer - Offer is a legal institution that has a mandatory character. The offer is a proposal for connection of the contract to a particular person, which in itself contains all the essential elements of the contract, so that the contract can be concluded upon acceptance of the contract. The offer may also be general when you are addressing some people. The legal bid effect is found in the production of the contract as the main purpose. The issue of bid revocation is the right of the one who has also offered. To make an offer or to sign a contract, the law does not foresee any form as a rule (Nerxhivane Dauti, 2004).

Some promises are made implicitly by the words or actions of the bidders / promises. For example, if Bob says to John: "I will wash and detail your car at 3:00 p.m today, if you bring it to my house, and if you pay me $ 50," then John brings his car to the house Bob at 3 o'clock in the morning and let him say nothing, then John has probably made an implied promise to pay Bob $ 50 for washing and detailing his car (Charles H. Martin, 2013).

Bid acceptance - the offer is considered to have been accepted when the Bidder receives the bidder's statement that he accepts the Bid. Also, the offer is treated as accepted even when the bidder sends the item or pays the price. Bid submission methods are usually dictated by how the bidder wishes the bidder to accept the bid or making a promise to do - facere or doing something required by the bidder or bidder. For example, if John says to Bob, "I will pay you $ 50 if you promise to wash and detail my car at 3:00 pm", John wants Bob to promise to do this job and do the promised job. This work which as a promise has a promise-for-a-promise is called a "bilateral" contract (Charles H. Martin, 2013).

Pre-contract - is a contract with which the obligation to enter into another contract is called the main contract.

Contract Object - The object of the contract may be a grant, action, inaction or patience.

Failures of will - The flaws of will are presented as: threat; essential mistake; Motivation of contracts without compensation; dispute; indirect declaration; fraud, fictitiousness.

Electronic contracts and electronic signatures

The Electronic Contract is one of the most obvious examples of how information and communication technologies (ICTs) can contribute to economic growth. It helps countries improve trade efficiency and facilitate the integration of developing countries into the global economy. This allows businesses and entrepreneurs to become more competitive. But knowing that an instrument (electronic contract) is powerful is not enough to ensure it is used best, we need to understand how it works, how to use it, and find creative ways for them putting this knowledge in practice, spreading it extensively and maximizing its power, Ronald Lee, (R.lee, 1998) who was one of the first to initiate electronic contracts as a concept more than a decade on first.

E-contracts are contracts that are executed and enacted by a software system in the sense that they are not concluded by face to face communications i.e. the "seller and buyer" or "supplier and consumer" do not meet in person to form, negotiate and execute the terms of their contract. Distance contracts is a type of e-contract because they are contracts concerning goods or services concluded between a supplier and a consumer under an organised distance sales which for the purpose of the contract, makes use of one or more means of distance communications such as internet, e-mails, telephones and so on up to and including when the contract is concluded (Lawteacher.net, June 2018).

Traditionally, when people have contractual agreements with one another, they have submitted a document, a physical copy signed by both parties, which is physically delivered, personally by the parties or via post, while over time and with increasing demand for exchange of goods and services between different countries, there is a growing demand for a faster way in order to overcome the barriers of distance and time.

For a contract to be formulated in a valid manner, certain elements must be completed, namely:

1. There must be an offer to determine the terms of the contract;

2. A clear receipt of the offer must be communicated to the person making the offer;

3. The contract must be supported by the review, eg; payment of the price;

4. Parties should aim to establish legal relationships;

5. All parties should have the legal capacity to carry out the transaction (Bateman Battersby, 2018).

However, in addition to the usual requirements for a paper contract, an electronically-contracted contract is legally valid if:

1. The contract is preserved appropriately and can be achieved after signing;

and

2. There has been consent between the parties to obtain information electronically, expressly or with implications.

One of the issues for electronic contracts is related to electronic signatures and it is the question of identifying a request for a purpose to establish contractual relations between the parties electronically, by signing the electronic parties the parties have the legal certainty that the contract concluded between the parties will be respected and will be legally valid.

Language and formal contracting procedures, employing technology for further standardization of certain classes of contracts in order to reduce transaction costs and contracting time is referred to as "Electronic Contracts". The first versions of the idea

were based on Electronic Data Exchange (EDI) as a communication medium. Since then, electronic contracts have evolved along with electronic communications.

1. Legal information:

The legal information that we propose directs the whole negotiation process and addresses the concerns over the legality of the transactions executed while using the electronic contract on the Internet.

Consumers in a distance selling contract for goods or services are entitled to certain rights which they can enforce in the advent of a dispute that may evolve in the contract and these rights which are provided by different laws includes;

Right of withdrawal

Right of cancellation

Right to refund and reimbursement of sums paid

Right to rescind the contract

It is also important to understand that these consumer rights are subject to some exceptions because it is not all types of goods these rights applies to and such goods will be considered in relation to the goods that were ordered. Where the supplier complies with regulation 8, the cancellation period ends on the expiry of the period of seven working days beginning with the day after the day on which the consumer receives his goods (Lawteacher.net, June 2018).

The legal information that helps in the formation of contracts is listed in. There are two methods by which information can be accessed:

1.1. Legal Information Websites - the electronic versions of some States as well as International Laws, which can be accessed via the Internet or for a subscription or non-payment fee. The purpose of subscribing to websites is not only to provide more electronic versions of laws and regulations, but also to create various forums that they could discuss with professionals from different fields for discussion purposes who could make a lot of recommendations for the users of these forums, in order to have as much information as possible about electronic contracts, while in the form of contracts, these sites could be a reference tool.

1.2. A particular contract form, or contracts, terms and conditions that accompany or are part of commercial documents used for the purpose of purchases or various transactions, have become the form of a contract model (Bled 2001).

2. Legal Infrastructure of the Electronic Contract

Many governments are developing legal infrastructure for monitoring and regulating transactions that are carried out through the Internet. As a change of plan, trading initiatives like Bolero are giving consumers an opportunity to utilize the legal

infrastructure they have developed and even make it mandatory for customers to sign and respect the rules when using these services.

In Bolero's (Bolero) heart is a unique legal infrastructure, the Bolero regulation. It connects users to a common set of rights and obligations in the electronic world (paperless).

It operates in accordance with national legal systems and international conventions.

The Bolero regulation is the result of one of the greatest legal feasibility in the world studies conducted by leading legal practitioners in the world trade law.

The rule drawn up by Bolero can be compared to that of a private contract. It does not neglect any of the trade agreements that are present in a contract. Instead, by signing the regulation, a user is responsible for the content of electronic documents sent through the Bolero workspace. Looking at the advancement that is taking place in different world countries, such as the United States or the European Union countries, whose main focus is to create more favorable business conditions, with a view to increasing trade international, respectively export of the products of the respective countries, therefore Kosovo and generally the Balkan countries should have a clear vision about how to design the legal path for the most advanced and safer use of the Electronic Contract and Signature electronics. Building a sustainable and advanced legal infrastructure would be one of the main priorities that the Kosovo government would have to deal with in the coming years, adaptation to the electronic system for the state of Kosovo would not be very difficult given that 65% of the population are of young age, and easily adapt to changes and advances in the electronic system (bolero).

There are different laws or legislations that govern e-contract most of which provide certain forms of redress and protection for parties to a contract most especially the consumer and they include;

The consumer protection (Distance Selling) Regulations 2000

The Electronic Commerce (EC Directive) Regulation 2002

Directive 2000/31/EC on electronic commerce

Directive 97/7/EC on consumer protection and distance contracts

Rome 1 convention on (contractual obligations)

There are also other laws which protect consumer rights with regards to distance selling contracts such as Unfair contract terms Act (1977) and the Unfair terms in consumer contracts regulations which applies in situations where the terms and conditions of the contract are not fair to the consumer and also to prevent significant imbalance in the rights and obligations of the parties to a contract, Sales of goods Act (1979) which gives the consumer the right to return the goods if there are not fit for their purpose and must be carried out within a reasonable time, Brussels 1 which protects the consumer when

conflict of laws and jurisdiction issues arise and provides that 'where there is a dispute as to whose law will apply with regards a dispute between both parties, the applicable law will be the law of the consumers "habitual residence" if the supplier directs his activities to that country by any means and even if the parties choose a different law, it should not deprive the consumer of their mandatory laws" because they are of the opinion that the consumer is the weaker party, Uncitral model law and so on (Lawteacher.net, June 2018).

Electronic commerce is focused on business among large companies or in consumer-oriented business online. The MEMO (Mareike Schoop) project tries to close the gap between these two areas by supporting e-commerce between small business and small business. Therefore, an electronic brokerage system is being developed which supports the research, negotiation and fulfillment stages of business partners, so in 1999-2001 it qualified as prof. Mareike Schoop, Ph.D, the time when the first legal structures about the advancement of electronic contracts began, and the big project where the participants of the project were the Netherlands, ABN-AMRO-Bank as project coordinator, Infolab of the University of Tilburg (NL), Origin of Spain, and several user groups including the Aachen Chamber of Commerce (IHK Aachen). The project started in January 1999 to complete in June 2001.

3. Preparation of the Electronic Contract:

3.1. In the case of negotiations where two or more parties are involved, several different versions of contracts are prepared until it brings to us a final agreement Means that facilitate the preparation of different versions of contracts as it may be. Contract Design - are some websites that are free of charge to assist in the drafting of electronic contracts that are part of the electronic contract system, the way these websites operate is that they pose some questions to which the user should answers you and then, the site automatically turns it into a standard form of electronic contract. these programs or pages are available to online users.

4. Supporting the Decision

This category includes functions that provide intelligent support to users while drafting contracts. In support of the decision tools should be made available through the outsourcing outsourcing process provided maximum support for users to make final decisions, which falls in cases where there are any ambiguities or do not understand any clause then through electronic forms the program be able to interpret the meaning of legal provisions or have a sub page where it can be linked and request additional clarifications (bled, 2001).

Electronic contracts and electronic signatures are as legitimate and enforceable as traditional contracts which are written on paper and signed into it, the law which made it possible for electronic contracts to be part of the global market was the International Act of Global Trade and Electronic Signatures (ESGICA), known as federal legislation

adopted in 2000, has made electronic contracts as legitimate as paper contracts themselves, this was a welcome news for all businesses , dealing with internet businesses, especially those companies that provided financial services, or insurance companies as well as those of household customer services and many other companies. The law has also assisted in the so-called Business with Business (B2B), which has been a necessity for businesses to be able to place orders for supply and to perform Internet services. This step has been a very important step since it has directly impacted on reducing business expenses and also lowering the cost to the customer (nolo).

So the electronic contract is an agreement created and signed in electronic form - in other words, there is no need to use printed papers. For example, you can write a contract on your computer and send it by email, a business associate, and the same by e-mail, accepted by the business associate who signed it by electronic signature and this shows the receipt of conditions and expresses his will to conclude the contract.

Contracts are merely an agreement between the parties, creating obligations that need to be enforced legally.

An electronic contract should contain:

Clear identification of contracting parties

The terms and conditions of the proposer or tenderer, presented in a clear and accurate manner.

The requested party or the receiving party must express its willingness to accept the contract at will.

And then the interactions between the parties for the execution of the contract, such as payment, delivery of goods or some other service, must begin.

Clear indication of contract validity (Michael Gisler).

The contract must have a valid signature from the parties involved in the contract confirming the acceptance of the obligations and the rights set forth in the contract. The signature must be accompanied by a date indicating the commencement of the validity of that contract.

Form of Electronic Contracts

There are many forms of electronic contracts but I will only mention two of the most important ones:

I. Click wrap (dashfarrow)

II. Brows wrap

I. In contrast to a Clickwrap Agreement is a web site requiring customers or users to first view the terms of an agreement by reading them, and then finally agreeing to the terms.

A ClickWrap Agreement is an electronic contracting tool with the user who appears at the end of a product. The terms and conditions of the Clickwrap Agreements are displayed on the same page as they should be accepted with "I Agree" (I agree) (James Douglas)

II. A Brows wrap agreement is when the terms of a contract or agreement are placed on a website, but often these conditions may be placed in a link when it is sent to the terms of the contract, so it is almost the same as saying we have entered into a super market, and in a certain part, the super market noticeable part of the consumer rights. So in this type of contract, the customer himself has to express more interest in the contract he accepts by clicking on the link and browsing the terms of the contract he accepts.

Why Use the Term "Wrap"

• If you bought a software program in the 80's or 90's it came wrapped in a thin layer of cellophane. It contained the floppy disks or CDs and a copy of the software license. These licenses were deemed "**shrinkwrap**" licenses.

• After the boom of the World Wide Web, software was delivered online and the licenses used retained the term"**wrap**", becoming "**browsewrap**" or "**clickwrap**"licenses (Mackenzie Hughes).

Thi is how it started long time a go to get the names that now we use everyday.

Judges, generally recognize the sellr's shrink-wrapped terms as an "Offer", and the buyr's acts, of opening the pacage and keeping the product beyond the return period, as an "acceptance (Charles H. Martin, 2013).

What are Clickwrap and Browsewrap Licenses?

Clickwrap Licenses

A software license (for actual software, website, application, etc.) that requires the user to affirmatively click on a button or checkbox with a term such as "I Agree", prior to use. – *Sometimes called a "click-through" or "click-to-accept" licence*

Users usually have opportunity to scroll through and review the terms prior to assent.

If the user does not agree with the terms he or she cannot precede, their only choice then is to not click on the "I Agree" button and not use the software.

Example: – By clicking on the "I Agree" button you are agreeing to be bound by the following terms and conditions, that where writen by the company.

Browsewrap Licenses

Browsewrap agreements are software licenses that do not require affirmative consent other than the user's initial or continued use of the software, website, or application.

The use combined with the knowledge of the terms and conditions of the browsewrap license are what constitute the user's assent.

Generally, courts will enforce browsewrap licenses only if the user had adequate and reasonable notice of the license terms.

Clients may want these licenses small, non-invasive and out of the way so they won't scare off potential users. You'll want the opposite, and may need to educate your client as to why its important. Drafting, maintaining and updating these licenses can create a perfect storm of legal, design and programming work. To draft and maintain these licenses properly you'll have to work closely with your client and their technical team to initially set up the license and for any updates (version 1.0, 2.0, etc.), thi sis how people know more about how to use click and browswrap, without having trubles with law.

Like any software licenses, clickwrap and browsewrap licenses are formal contracts that contain property rights. Being contracts, traditional rules of contract law still apply.

Most cases hinge on whether there was (1) either actual or constructive notice or (2) assent by the user.

Whether the user of the software actually knew, impliedly knew, or should have reasonably known, about the terms of the license before he or she clicked to agree or used the software.

Implementing Online Agreements

In recent courts that have decided how to deal better with the different types of online deals. In general, courts have been hesitant to implement Browse-wrap deals, giving them more fairness and allowing the implementation of the Clickwrap Agreements. The reason for this is that through the click wrap notice to the customer or user in any kind of deal is easier. Courts have argued that users are more likely to be aware of all terms and conditions when they are required to read and accept terms and conditions placed in front of them on the web site under a Clickwrap agreement (dashfarrow).

However, this does not make a Browse-wrap agreement completely unacceptable, since it is assumed that a customer who wants or is interested in a particular product wants to know his / her rights and with this website is obliged to place in a visible place the terms of the contract or to mention the link which indicates the terms and conditions of the contract.

As far as electronic contracts are concerned, in Kosovo they are not regulated by a separate law and are not mentioned in any law at all, so we can say that they are not protected by law, nor are they being used by businesses all this due to the economic isolation that Kosovo had until the beginning of 2016, when with the stabilization and association agreement, Kosovo was opened for the European market as well.

Meanwhile, unlike Kosovo, the Republic of Albania is a step forward by regulating it with three separate laws, namely:

Law on Electronic Document (LDE)

This law regulates the use of electronic documents by natural, legal, public and private persons whose electronic programs and devices enable the realization, production, transmission, receipt, storage and security of electronic document information.

The Law on Electronic Signature (LNE)

The purpose of this law is to create the necessary legal framework for the recognition and use of electronic signatures in the Republic of Albania.

The Law on Electronic Commerce (LTE)

The purpose of this law is to establish rules for the conduct of electronic commerce actions, through the services provided by the information society, on the protection of the participants, the legal protection of the customer's confidentiality or the confidential data of the participants, and to ensure the free movement of information services, defining the responsibilities of the information society service provider.

Electronic Signature

"Electronic signatures" are all electronic data, which are are attached or logically associated with other electronic data, which serve as a way of certifying the signatory's identity and the authenticity of the signed document. An electronic signature is an electronic verification tool. This term is usually defined as a verification of the holder's identity. Any type of electronic verification shall be considered as an electronic signature as long as it is associated with other data in electronic form.

The term electronic signatures have been given a broad meaning and are specifically considered "electronic data, which are logically linked to other data electronically and serve as a verification method." These data may be code, picture, seals etc. Also, it should be clear that the term electronic signature is directly related to the verification of data and has nothing to do with actions such as using a PIN code to enter a bank account. Here we do not use electronic signatures. As you enter the same code to confirm a financial transaction, it's an example of data verification and is therefore considered an electronic signature. An advanced electronic signature is an electronic signature that meets the following 4 requirements:

I. It is affiliated uniquely with the signatory;

II. Is capable of identifying the signatory;

III. It is designed in such a way that the signatories have sole control over the signature;

IV. Relates to the data in such a way that any further change can be distinguished (guide).

Whereas, qualified electronic signatures are advanced signatures but rely on a qualified certificate, thus issued by a legally recognized Certification Service Provider as such. For ease of use, it is called electronic signature. Also, it should be remembered that the signatory is not the person who creates the signature, but is the person who owns the signature creation device. An ordinary example of signature equipment is a smart card, flash drive, and so on.

The electronic signature can not be used in some specific areas, such as legal actions in the field of family law and inheritance, legal actions that require a public legalization, a notary act or requiring a court order.

The law does not extend to issues related to the validity and disruption of contracts or other legal obligations under the requirements set forth by other laws or by different states. An electronic signature is considered invalid if the security requirements foreseen in the law are not met (nolo).

To be as secure as an electronic signature, it should contain more or more difficult symbols or texts in order to avoid falsification or misuse, so consumers and businesses are hesitant or better to say that they are accessing this activity more difficult, but electronic signing and electronic contracts increase trust between businesses and between individuals and businesses as signing and signing an electronic contract and using an electronic signature should have a great deal of confidence, but this it also has a positive side as it reduces costs and costs, and also significantly increases efficiency and thus the efficiency of businesses increases significantly and the customer will be more satisfied. It should always be noted that extraordinary care has to be taken and the conditions of electronic contracts need to be read more carefully, as in recent years the potential abuse, electronic contracts and e-signatures have increased considerably as a consequence of the increasing popularity of electronic contracts electronic contract.

European Union Directive on Contract and Electronic Signature:

The European Union has implemented the model law through both directives; The Electronic Signature Directive and the Electronic Commerce Directive. Following the insistence of the European Commission, the European Union's directive was updated in 2000, after many researches and discussions, this directive has a total of 14 articles, the same directive was revised several times and updated in order to function as best as possible. to be as clear as possible what is contained in this directive of the European Union through this Directive, many countries have started and regulated their own domestic laws, ie they have harmonized the laws on electronic signature in relation to the directive of the European Union regarding the contract and the Electronic Signature, four annexes are included in this Directive, which clarify the content of the directives (Official Gazette).

Implementation of the directives:

1. Member States shall adopt and implement by-laws, by-laws and administrative provisions which are necessary to comply with the legal obligations of this Directive before 19 July 2001. The Member States shall inform the Commission thereof. When adopting these measures, Member States shall mention the correlation between them and this Directive within the measures concerned or during their official publication. Methods for making this reference are determined by member states.

2. Member States shall communicate to the Commission the text of the main provisions of domestic law which they adopt in the field governed by this Directive (EU).

Major changes can be made since the entry into force of this directive, since since the entry into force of this directive the European Union has had a smaller number of states, and later with the addition of the number of members and with the increasing use of technology as technology advances, many other circumstances have changed as sophisticated tools for using information technology, and thus the potential misuse and risk of electronic signature management and electronic contracts have advanced to an extremely high level, and their use has increased too much, now many countries also have regulated through domestic legislation the use of electronic contracts and electronic signatures and as a result of this our modern society relies on an economic system based on the perpetrator is in the contract mechanism. For now, our industrial and service society is changing for a more modern and advanced society as well as access to information. One of the most important indicators showing this difference is the growing digital economy. But without any confidence of the economic community in electronic contracts, the new economy will not be able to reveal its full potential and good for our society, which will be behind the potential of new technology, what is capable of offer. Or we can build trust in technical solutions to contracts

Surely it is easier to create a technical solution for electronic contracts to be legally valid than to redefine a legal mechanism that exists since centuries, here it is about classical contracts. But on the other hand, a legal system that was generated thousands of years ago does not have the basics needed to incorporate modern communication modes, such as various modern contracting tools, such as electronic contracts and electronic signatures, we will need review the laws and draft a new law that would make the "Secure Electronic Contracts (Katarina), (SECO)" permissible and protected.

E - Governance in Kosovo

Electronic governance (rks-gov) is the provision of governmental services through information and communication technology (such as WAN, Internet, mobile network) to citizens, businesses and other categories. With the application of e-government, citizens and businesses, but also the government itself, will have effective and quick services, access to the service from every point and distance, stimulation of economic and social development, opportunities for capacity building, permanent services in any time,

presentation of national achievements, etc. The Republic of Kosovo, being actively involved in the regional and European developments processes, will also engage in e-government and ICT governance in the region and Europe. As a participant in international forums, Kosovo will realize all its obligations to develop the information society in full cooperation and partnership with the stakeholders. However, electronic governance does not only need European and regional integration but in particular we need to create a very important pillar of economic development and overall progress of Kosovo society(kryeministria).

Kosovo regarding electronic contracts and electronic signatures does not have a specific law, but for these in the strategy of the Government of Kosovo. Only in "E-Commerce" is writed that "e-commerce - Electronic commerce has to do with commerce that is carried out electronically using the Internet. This is closely related to the presentation of different products via the Internet (e-business) but by using the identity electronic can be realized electronic contracts of different sizes".

Conclusion

The rationale behind e-contracts is to enhance the operations of businesses today by providing faster and better means whereby transactions can take place without the parties having to leave their homes or meeting face to face. Considering this Kosovo has to create the law that regulate electronic contracts and electronic signature. A supplier can simply create a web site and advertise their goods and a consumer if interested can simply place an order through the web site and from that stage proceed to create a contract by following the necessary steps provided for him by the supplier to conclude a contract, this should start to be used more in our country becouase its more faster and easy to trade goods online than to wait untill kosovo has the visa liberations to travel to create contracts face to face.

An electronic contract is a contract concluded through electronic means. So apart from the form it seems that it has no distinction with classic contracts or regular contracts. The rights and obligations of the parties are the same, depending on the contract they bind, and by law in many countries are protected electronic form or electronic use, whereas regarding the contract as a contract in many states the defense refers to the civil code of the respective state, means its protection in case of dispute is made for those points that are not regulated by the law on the electronic contract and the law on electronic signature, the Civil Code states. The electronic contract has a very favorable approach towards globalization, or to the digitalization we are going to, as we see each other day, that we are moving towards a world of information technology, which means a world that favors everything related to digitalization , so the electronic contract is increasingly occupying a considerable amount of space on the world market due to the numerous commercial transactions being used precisely because of the advantages that this contract offers, as well as Speed and Flexibility are two of the the most specific features of the electronic contract, as the parties through it can enter into contractual

relations in a very short time and agree on all the rights and obligations, and no matter where the world can to find one side or the distance between the sides no matter how l Arg may be parties can very easily conclude contracts through electronic contracts. Electronic contracts also have an extraordinary advantage, since through them or by utilizing them, parties can easily perform bank transactions at any time, thus eliminating many of the obstacles that have emerged beforehand. Problematic or negligent side the advantage of the electronic contract is first of all the scams or multiple chances of misusing the electronic signature and the electronic contract can be misused easily if only a little is not careful, so you should be very careful when using the electronic contract especially when using the signing electronic, using the most unique way for electronic signature.

Bibliography

[1] Nerxhivane Dauti, Contracts (for master studies), Prishtina 2012, pp.9-10.

[2] Nerxhivane Dauti, The Right of Obligations (General Part) Prishtina, 2004,

[3] Charles H. Martin, Every1's Guide to Electronic Contracts, 2013, p.28 Chap. 4

[4] https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1948069 Ronald M. Lee, Decision Support Systems, Vol. 4, No. 1, 1988, pp. 27-44; date.01.04.2018

[5] All Answers ltd, 'E commerce and E Contracts' (Lawteacher.net, June 2018) <https://www.lawteacher.net/free-law-essays/commercial-law/e-commerce-and-e-contracts-commercial-law-essay.php?vref=1> accessed 19 June 2018

[6] https://www.batemanbattersby.com.au/electronic-contracts-electronic-signatures-valid/ Bateman Battersby Lawyers,(viewed on: 21 May 2018, 13: 35h)

[7] All Answers ltd, 'E commerce and E Contracts' (Lawteacher.net, June 2018) <https://www.lawteacher.net/free-law-essays/commercial-law/e-commerce-and-e-contracts-commercial-law-essay.php?vref=1> accessed 19 June 2018

[8] A Survey of Electronic Contracting Related Developments, "14th Bled Electronic Commerce Conference", Bled, Slovenia, June 25-26, 2001, p.497 (viewed: 29 February 2018, 23: 31h)

[9] BOLERO (Bills of Lading Electronic Registry Organisation) is a pilot project funded partially by the European Union in 1994. 'Bolero.net' is the legal structure for paperless international trade launched in September 1999. http://www.bolero.net/home/rulebook-and-title-registry/(viewed: 12 February 2018, 20: 30h).

[10] http://www.bolero.net/home/rulebook-and-title-registry/(viewed: 12 February 2018, 20: 30h).

[11] All Answers ltd, 'E commerce and E Contracts' (Lawteacher.net, June 2018) <https://www.lawteacher.net/free-law-essays/commercial-law/e-commerce-and-e-contracts-commercial-law-essay.php?vref=1> accessed 19 June 2018.

[12] Mareike Schoop, Thesis type: PhD, http://dbis.rwth-aachen.de/cms/theses/thesis-2

[13] A Survey of Electronic Contracting Related Developments, "14th Bled Electronic Commerce Conference", Bled, Slovenia, June 25-26, 2001, p.497 (viewed on February 2018)

[14] http://www.nolo.com/legal-encyclopedia/electronic-signatures-online-contracts-29495.html (viewed on 27 February 2018, 19: 30h)

[15] Michael Gisler "Legal Aspects of Electronic Contracts" Infrastructures for Dynamic Business-to-Business Service Outsourcing (IDSO'00) Stockholm, 5-6 June 2000 (viewed: 28 February 2018, 22: 19h)

[16] Mackenzie Hughes LLP, ”Drafting Clickwrap and Browsewrap Agreements:Advanced Strategies for Enforceable Online Contracts”

[17] Charles H. Martin, Every1's Guide to Electronic Contracts, 2013, p.110 Chap. 3

[18] Guide to the Use of Electronic Signatures, Instruction no. 001, Bulletin September 2011, Version 1.3, Republic of Albania.

[19] http://www.nolo.com/legal-encyclopedia/electronic-signatures-online-contracts-29495.html (watched on: February 28, 2018, 01: 22h)

[20] (eu), Regulation 1999/93 / EC of the European Parliament and of the Council, Brussels, 13 December 1999 (as revised on 28 February 2018, 21: 22h)

[21] Katarina Stanoevska-Slabeva, Legal Aspects of Electronic Contracts, University of St. Gallen, https://pdfs.semanticscholar.org/fd12/b48c3c8fc96a0ca31137f62fdc93a9c2e6c6.pdf

[22] (seco) Secure Electronic Contract (viewed on: February 30, 2018, 23: 22h)

[23] Electronic governance , https://map.rks-gov.net/institucion/Plan-and-Strategies/Strategjia-e-e-qeverisjes.aspx?lang=en-US

[24] http://www.kryeministriks.net/repository/docs/STRATEGJIA_E_QEVERISJES_ELEKTRONIKE_2009_2015.pdf (viewed on: 28 February 2018, 24:06h)

[25] Electronic Document Law (LDE) ,Albanian Law.

[26] Electronic Signature Law (LNE), Albanian Law.

[27] Law on Electronic Commerce (LTE), Albanian Law.

[28] Official Gazette L 013, 19/01/2000 p. 0012 - 0020, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A51998AG0326%2803%29 (watched on: 28 February 2018, 01: 22h)

[29] July 19, 2012, http://www.dashfarrow.com/website-agreements-browse-wrap-vs-clickwrap-agreements/ (viewed on 28 February 2018, 20: 33h)

[30] July 19, 2012, http://www.dashfarrow.com/website-agreements-browse-wrap-vs-clickwrap-agreements/ (viewed: 28 February 2018, 23: 33h)

[31] James Douglas, May 1, 2015, https://legalvision.com.au/click-wrap-agreement-v-browse-wrap-agreement/ (viewed on: 27 February 2018, 00: 43h)

[32] Granit Curri, Kolegji Aab – paper- 2015, fq.8-9

ISSN 2601-8683 (Print)
ISSN 2601-8675 (Online)
European Journal of
Formal Sciences and Engineering
January - June 2020
Volume 3, Issue 1

Biodynamic Synchronized Coupled Model for Crowd-Footbridge Interaction

Marcelo André Toso

Federal Institute of Santa Catarina, Xanxerê, SC, Brazil

Herbert Martins Gomes

Federal University of Rio Grande do Sul, Porto Alegre, RS, Brazil

Abstract

Nowadays there are growing interests in vibration serviceability assessments of composite footbridges. The new design trends of composite footbridges make them slender civil structures that may be affected by the load action of walking pedestrians resulting in large deflections or even uncomfortable vibrations. Furthermore, the presence of people on the footbridges causes the addition of mass to the structural system and due to the human body's ability to absorb vibrational energy, an increase in structural damping. In this paper, the interaction between pedestrian and structure is modelled using data from pedestrian characteristics and vibration data from a measured footbridge as a comparison basis. A previously developed numerical model was used, this model called Biodynamic Synchronized Coupled Model (BSCM) consists of a fully synchronized force model in the longitudinal and lateral direction of pedestrian's movement and a biodynamic model with mass, damping and stiffness parameters. The model is coupled with the structure using the Finite Element Method at the feet's contact points. Pedestrians are treated as individuals with intrinsic kinetic and kinematic parameters following a measured correlation matrix obtained by the use of an especially designed force platform. Finally, the adequacy of the proposed model to represent the pedestrians as BSCM for the walking effects on the structure is investigated by experimentally measured accelerations on a footbridge (freely walking). The numerical results show good agreement with the experimental results.

Keywords: footbridges, human-induced vibration, crowd-footbridge interaction, walking, natural frequencies.

1. Introduction

Several cases of excessive vibrations have been studied in the past that are related to pedestrians' footbridges. Cases of unstable footbridges such as the Millennium Bridge in

London and the Solferino Footbridge in Paris have attracted professional attention. These footbridges presented large vibrations on their opening days (Dallard et al. [1]). Many footbridges have natural frequencies that are coincident with the dominant frequencies of the pedestrian induced load and therefore they have the potential to undergo excessive vibrations. It is noteworthy that humans are quite sensitive to vibration in a low-frequency range of whole-body vibrations where natural frequencies of the human body limbs and systems can be observed. Therefore, there are recommendations related to human body vibration, for example, ISO 2631 [2] which define limitation curves for exposure times in some frequency ranges. This paper presents a study on the interaction between walking pedestrians and a flexible footbridge. The paper uses some previous investigation results (Toso et al. [3] and Toso and Gomes [4]). A Biodynamic Synchronized Coupled Model (BSCM) is used to analyze the pedestrian structure interaction. This model brings together interaction in 3D with several 1 DOF models to model human crowds walking and interacting with structures. In the longitudinal and transversal direction of movement a Fully Synchronized Force Model (FSFM) is used and in the vertical direction, it is combined with a biodynamic model (mass-spring-damper parameters) that is coupled to the structure. Besides, experimental data for a real footbridge considering a pedestrian crowd are presented which confirms the trends suggested by the numerical modeling.

2. Literature Review

Zivanovic et al. [5] state that the pedestrian-structure-interaction needs to consider in footbridges design, mainly in the design of slender structures that are dynamically excited by humans. Excessive vibrations may cause discomfort to pedestrians and potential deterioration of the footbridge's structural integrity. Stoyanoff and Hunter [6], report that the natural frequencies of short-span footbridge are usually not susceptible to pedestrian vibrations. However, when the distance between the spans increases, the natural frequencies of the structure decrease, and the human occupation and interaction on them becomes a concern due to the resonance phenomena. The authors state that, during walking, vertical forces produce frequencies between 1.5 and 4.0 Hz, while lateral forces produce frequencies between 0.75 and 2.0 Hz. Considering lateral oscillations, Bodgi et al. [7], state that a crowd on a footbridge imposes a lateral dynamic excitation on the structure at a frequency close to 1.0 Hz. When the first vibration mode decreases, being in the same range as the human step rate, the resonance may occur. Consequently, there is an increase in the oscillation amplitude of the structure and the pedestrians are forced to change their natural gait. If the amplitude of oscillation is large enough, the phenomenon called pedestrian-structure synchronization occurs. Researchers such as, Wheeler [8] state that the crowd effect is not significant unless the pedestrian's step rate is close to 2.0 Hz. The author affirms that the effect of the pedestrian crowd on a footbridge with fundamental frequency away from the typical step rate (2.0 Hz) may be negligible because the vibratory response of the structure may be lower when compared to a single pedestrian walking at a frequency identical to the fundamental frequency of

the analysed structure. Qin et al., [9], evaluated the dynamic response of a footbridge (analytical study) considering a single pedestrian and the effects of interaction between human-structure. The analysed footbridge was modelled as a simply supported Euler-Bernoulli beam with uniform cross-section. The pedestrian damping varies over time, considering the individual's walking speed. A controlled force was used to compensate the energy dissipated during walking. The effects of stiffness and damping of the human body were investigated. According to the authors, for a flexible structure, the pedestrian-structure dynamic interaction is greater when compared to a rigid structure. There is also potential elastic energy of the individual's legs, "tending to separate the pedestrian from the structure," being greater when the individual is near to footbridge mid-span. As result of the interaction between pedestrians and flexible structures, it is noted that the individual must impose more external energy and modify the walking pattern to maintain his steady gait and a relatively uniform dynamic behavior of the body's center of mass. Recently, Tubino [10] proposed a numerical model that accounts for pedestrian structure coupling in the vertical direction. The footbridge was modelled as a continuous unidimensional beam dynamic system, while pedestrians were schematized as moving single-degree-of-freedom systems with random dynamic properties. The paper results show possible variations of damping ratio and natural frequency in the coupled system based on the random pedestrians' parameters. Regarding pedestrian loads, these forces have been determined from investigations using force platforms, treadmill machines, and even prototype footbridges, in which the applied force is the amount produced by a single walking pedestrian. The combined force applied by individuals is considered for groups of pedestrians or crowds. Thus, the design load is a force model. To analyse the analytic human-induced loads, most of guidelines, for instance, SETRA [11] and ISO 10137 [12] often consider three to five harmonics of the frequency spectrum of ground reaction forces (GRF). During walking, a pedestrian produces dynamic forces with components in three directions: vertical, lateral and longitudinal to the footbridge. The vertical component is generated by the impact of supporting the body weight on each leg alternately. In the lateral direction, the forces are generated by the periodic balance of the body when changing legs. Finally, in the longitudinal direction, the force is the result of friction between the foot and the floor, as well as the acceleration and deceleration of the body in this direction. Using force platforms, some researchers (Harper et al., [13]; Galbraith and Barton, [14]; Blanchard et al., [15]; Kerr, [16]) conclude that the vertical component of the resultant force of an individual has two peaks and a valley as shown in Figure 1. The other force components are also present in the figure.

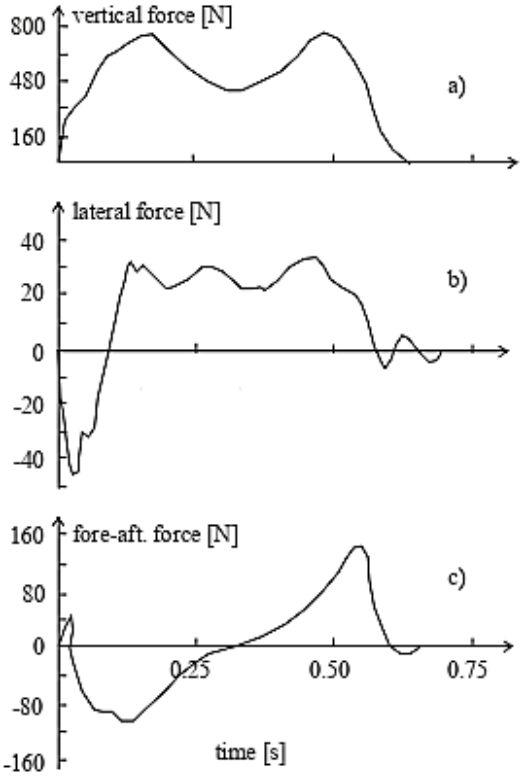


Figure 1: Typical forces during walking: (a) vertical, (b) lateral and (c) longitudinal direction. (Zivanovic et al. [5]).

3. Methodology

This paper proposes to assess the pedestrian-structure interaction using data from an experimentally measured footbridge as a basis for comparisons. In the longitudinal and transversal direction of movement a Fully Synchronized Force Model (FSFM) is used and in the vertical direction, it is combined with a biodynamic model (mass-spring-damper parameters) that is coupled to the structure (herein called, BSCM, Biodynamic Synchronized Coupled Model). The biodynamic model considers the synchronization of the three force components applied in space (positions where they should be applied) and in time (peak and valleys of the three force components occurring synchronously at the proper time) with a spring-mass-damper model, coupled continuously with the structure's FEM. Following the use of the BSCM, the mid-span RMS (root-mean-square) acceleration of a footbridge structure is evaluated to check its serviceability. For the applied BSCM, kinetic (forces) and kinematic (speeds, pacing rate, step length, and step width) parameters are used. Then the BSCM results are compared with the FSFM and these results are compared with experimental data.

3.1. Force Models

Design Codes use simplified force models to represent the force magnitude from successive footfalls. These models assumes forces acting in a straight line along the direction of walking at a constant speed (SETRA Guideline [11] and ISO 10137 [12]). This is a very common assumption for the analysis and design of footbridges. It is obvious the major disadvantages in using this simplified model as it lacks for dynamic interaction (only time-varying forces are used) and the spatiality and synchronization of application of the three forces components. SETRA Guideline [11] and ISO 10137 [12]) use force models to vertical, lateral and longitudinal direction of the walking, based in Fourier series. Overall, these models produces acceleration unsafe values, since they are based on excessively simplified load models. Then, it is necessary to incorporate other parameters to simulate the pedestrian-structure interaction (for instance, considering biodynamic models). Furthermore, in a recent publication Toso et al. [3] proposed a force model called Fully Synchronized Force Model (FSFM). In that model, the changes in velocities during the walking (single and double stance phase) were considered and they were synchronized in time and space. The authors pointed that the pedestrian speed in the double stance phase is greater than at single stance phase. This speed is also greater than the average speed of the pedestrian. Another important characteristic is that human walking does not occur in a straight line in the direction of walking (as proposed by Guidelines). There are parameters like step length and step width that influence the application of the resulting force. Using a specifically designed force platform, these kinematic parameters were measured, and average values for a test campaign with 54 subjects were presented by Toso et al. [3]. In that proposed force model, peak and valley values from each force component should be placed accordingly in the right position of the contact surface and the model's reference time adjusted to the correct phase. Thus, there is a spatial and temporal synchronization of the three ground reaction force components. More details about the Fully Synchronized Force Model (FSFM) can be found in Toso et al. [3].

3.2. Biodynamic Synchronized Coupled Model

In the literature, there is a consensus that shifts in the structural natural frequencies are not observed when modelling the pedestrians using force-only models. This will only be present, as indicated by experimental measurements of a crowd of pedestrians crossing footbridges, if mass, dissipative effects, and synchronism of applied loads are taken into account. Another observed feature is the structural damping increase when considering pedestrians like biodynamic models. This is attributed to the human body's ability to absorb energy, a feature represented only when introducing the biodynamic models. In this paper, the FSFM (Fully Synchronized Force model) is merged to a biodynamic model resulting in the so-called BSCM (Biodynamic Synchronized Coupled Model) composed of mass, damping, and stiffness, with a single degree of freedom (SDOF) that represents the action of a walking pedestrian in the vertical direction. Afterward, the model's degree of freedom is continuously coupled to the structure in the places where the feet have

contact with the floor and replicated to represent a pedestrian crowd. This replication takes into account intra and inter-subject variability (mainly due to subject's weight, height, step length, step width and pacing rate). This makes possible to analyze the structural behaviour according to distinct crowd densities in a systematic way. Toso and Gomes [4] proposed this model, where a biodynamic model with synchronization of the three force components applied in space (positions where they should be applied) and in time (peak and valleys of the three force components occurring at the proper time) was presented. This biodynamic model is coupled continuously with the structure's FE Model. The biodynamic model has been conceived in a way that the actuator force is the main source that drives the human will for walking, generating oscillations in the vertical direction. The actuator reasoning is based on experimentally obtained vertical force (using a force platform) and acceleration data (using an accelerometer attached to the pedestrian's body waist). This allows the fit of the biodynamic model (with actuator) in order to match measured vertical ground reaction force and acceleration along time, in a rigid platform. It is important to note that, for flexible structures, the interaction force will change as the flexible structure add a relative displacement to the biodynamic model. A biodynamic model for flexible structure, including mass, damping, stiffness and actuator that is coupled to the footbridge in the vertical direction is considered, according to Figure 2.

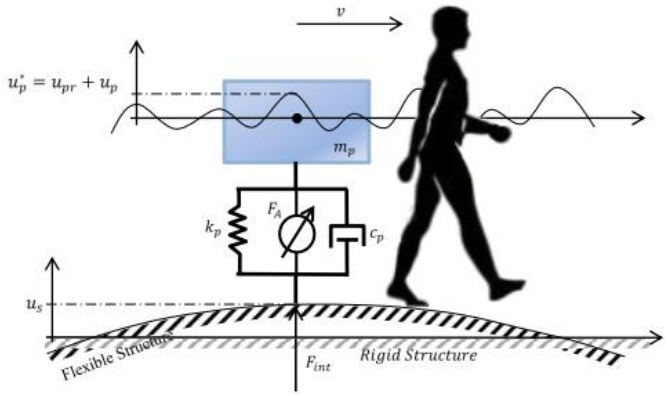


Figure 2: The biodynamic single degree of freedom system composed of mass, damping, stiffness and actuator and flexible structure situation.

In this figure, u_p^* is the pedestrian vertical displacement around the center of mass in the initial equilibrium rest configuration, considering a rigid and a flexible structure; c_p and k_p are the damping and stiffness of pedestrian; F_A is the vertical actuator force; v is the pedestrian speed; m_p is the pedestrian modal mass; u_s is the structural displacement and F_{int} is the interaction force.

The model proposed allows assessing interactions with both rigid and flexible structures. Toso and Gomes [4] presented a complete description of the model; here it is

showed some equations to evaluate the pedestrian structure interaction. Equation (1) represents the pedestrian's interaction force $\{\boldsymbol{F_{int}}\}$ when walking on a flexible structure, according to presented in Figure 2.

$$\{\boldsymbol{F_{int}}\} = \{\boldsymbol{H}(e,\xi_0)\}^T[-c_p(\dot{u}_p - \{\boldsymbol{H}(e,\xi_0)\}\{\dot{\boldsymbol{u}}_s\}) - k_p(u_p - \{\boldsymbol{H}(e,\xi_0)\}\{\boldsymbol{u}_s\}) + F_R] \quad (1)$$

Here: $\{\boldsymbol{H}(e,\xi_0)\} = [0\ 1\ 0]_{1\times3}[\boldsymbol{N}^e(\xi_0)]_{3\times6}[\boldsymbol{Q}]_{6\times n}$. Where $[\boldsymbol{N}^e(\xi_0)]_{3\times6}$ is the shape function, assuming a plane structural beam Euler-Bernoulli finite element; $[\boldsymbol{Q}]_{6\times n}$ is used in order to evaluate only the displacements in the vertical direction at the contact point; u_p and $\dot{u}_p$ are the displacements and velocities related to the interaction between pedestrian and flexible structure; $\{\boldsymbol{u}_s\}$ and $\{\dot{\boldsymbol{u}}_s\}$ are the displacements and velocities related to structure; F_R is the pedestrian vertical reaction force, measured in a rigid structure.

3.2.1. Linking the biodynamic model to the structural equations of motion

Equations (2), (3) and (4) represent the matrices of the coupled system (pedestrian and structure), that takes into account mass, damping and stiffness respectively.

$$[\mathbb{M}]_{\boldsymbol{n+1}\times\boldsymbol{n+1}} = \begin{bmatrix} [\mathbf{M}]_{\boldsymbol{n}\times\boldsymbol{n}} & \{\mathbf{0}\}_{\boldsymbol{n}\times\mathbf{1}} \\ \{\mathbf{0}\}^{\boldsymbol{T}}_{\mathbf{1}\times\boldsymbol{n}} & m_p \end{bmatrix} \quad (2)$$

$$[\mathbb{C}(t)]_{\boldsymbol{n+1}\times\boldsymbol{n+1}} = \begin{bmatrix} [[\boldsymbol{C}]_{\boldsymbol{n}\times\boldsymbol{n}} + \boldsymbol{C}^*(i)_{\boldsymbol{n}\times\boldsymbol{n}}] & -\{\boldsymbol{H}(e,\xi_0)\}^T c_p \\ -\{\boldsymbol{H}(e,\xi_0)\}c_p & c_p \end{bmatrix} \quad (3)$$

$$[\mathbb{K}(t)]_{\boldsymbol{n+1}\times\boldsymbol{n+1}} = \begin{bmatrix} [[\boldsymbol{K}]_{\boldsymbol{n}\times\boldsymbol{n}} + \boldsymbol{K}^*(i)_{\boldsymbol{n}\times\boldsymbol{n}}] & -\{\boldsymbol{H}(e,\xi_0)\}^T k_p \\ -\{\boldsymbol{H}(e,\xi_0)\}k_p & k_p \end{bmatrix} \quad (4)$$

One way to solve the time domain Equation of motion is by using direct numerical integration. In this paper, the Newmark integration scheme (Bathe [17]) is used in order to evaluate the structural response considering all the structural vibration modes.

Toso and Gomes [4] showed that considering a three-dimensional truss element, the human-structure interaction model can be evaluated using the Equation (5):

$$\begin{bmatrix} [\mathbf{M}] & [\mathbf{0}] \\ [\mathbf{0}] & diag\{\boldsymbol{m}_p\} \end{bmatrix} \begin{Bmatrix} \{\ddot{\boldsymbol{u}}_s\} \\ \{\ddot{\boldsymbol{u}}_p\} \end{Bmatrix} + \begin{bmatrix} [[\boldsymbol{C}] + [\boldsymbol{H}]^T diag\{\boldsymbol{c}_p\}[\boldsymbol{H}]] & -[\boldsymbol{H}]^T diag\{\boldsymbol{c}_p\} \\ -diag\{\boldsymbol{c}_p\}[\boldsymbol{H}] & diag\{\boldsymbol{c}_p\} \end{bmatrix} \begin{Bmatrix} \{\dot{\boldsymbol{u}}_s\} \\ \{\dot{\boldsymbol{u}}_p\} \end{Bmatrix} +$$

$$\begin{bmatrix} [[\boldsymbol{K}] + [\boldsymbol{H}]^T diag\{\boldsymbol{k}_p\}[\boldsymbol{H}]] & -[\boldsymbol{H}]^T diag\{\boldsymbol{k}_p\} \\ -diag\{\boldsymbol{k}_p\}[\boldsymbol{H}] & diag\{\boldsymbol{k}_p\} \end{bmatrix} \begin{Bmatrix} \{\boldsymbol{u}_s\} \\ \{\boldsymbol{u}_p\} \end{Bmatrix} = \begin{Bmatrix} \{\boldsymbol{F}(t)\} \\ \{0\} \end{Bmatrix} - \begin{Bmatrix} \{\boldsymbol{F_R}(t)\} \\ \{0\} \end{Bmatrix} \quad (5)$$

where $diag\{\boldsymbol{m}_p\}$, $diag\{\boldsymbol{c}_p\}$ and $diag\{\boldsymbol{k}_p\}$ will contain the mass, damping and stiffness parameters of each of the pedestrians.

4. Numerical and experimental results

The analyzed structure is located in the city of Brasília, Brazil. It is a composite footbridge (34.08 m in length, 2.4 m in width and 2.25 m in height). The footbridge roof is built with a curved reinforced concrete shell. The deck floor consists of reinforced concrete planks that are simply supported on the truss members that link the left and right side of the footbridge. The handrails consist of hollow tubular steel bars. Additional information, design details, materials properties, etc. can be found in Brasiliano et al. [18]. Figure 3 shows the analyzed footbridge.

Figure 3: Analyzed footbridge.

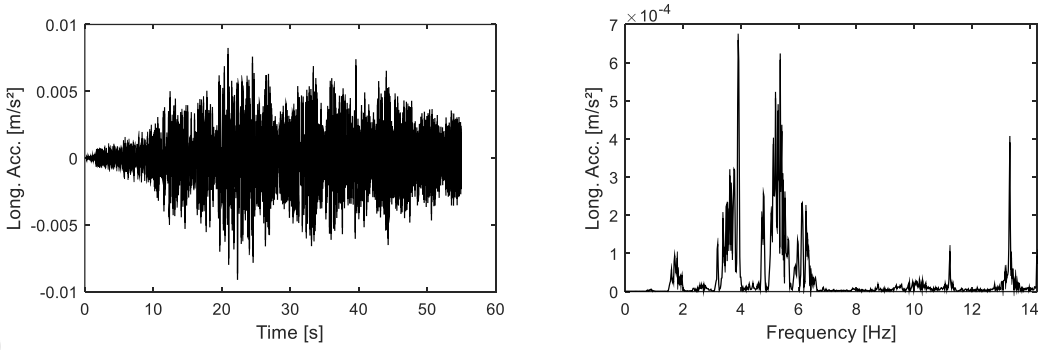
4.1. Numerical model results

In this topic, a dynamic analysis is performed to investigate the footbridge dynamic behaviour under a pedestrian crowd (0.25 pedestrians/m^2). This analysis consider: (a) a Biodynamic Synchronized Coupled Model (BSCM) that considers an actuator in the vertical direction of each pedestrian, and a fully synchronized force model as mechanisms for the willingness of walk, in a number that represents some crowd; (b) a Fully Synchronized Force model (FSFM) to vertical, longitudinal and lateral directions. The two models use the dynamic load factors proposed to SETRA Guideline [11] for force estimation. Both models assume the entry of the pedestrians on the footbridge is randomly generated, considering the effective width of the structure and keeping the specified crowd densities. Pedestrians and their characteristics are represented using random variables, following a Gaussian distribution based on average parameters, coefficients of variation and a correlation matrix of experimental data. Monte Carlo method is used to obtain the pedestrian's kinematic parameters, which results in different pacing frequency, step length, step width etc. for each individual (Toso et al. [3]). Regarding to biodynamic parameters, Toso et al. [19] proposed a single degree of freedom (SDOF) biodynamic model to obtain the following parameters: mass (m),

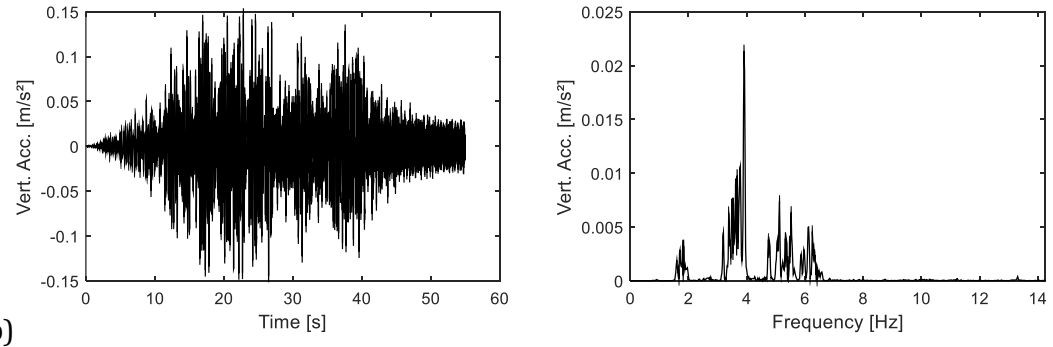
damping (c) and stiffness (k). In this paper, those equations were used to corresponding to the data of the analysed crowd. These biodynamic parameters are used in Equation 5.

Individuals have different characteristics, for instance height, mass, pacing rate etc. According to Toso et al. [3], the crowd characteristics are modelled based on mean value and standard deviation of the group of pedestrians being modelled. Each random variable follows a correlated Gaussian distribution based on experimentally obtained data. So, for the number of pedestrians that are to be modelled, samples are generated based on a correlated Gaussian distribution for these parameters. Besides, it is also reasonable to assume that for a specific individual, there are some trends in the kinetic and kinematic parameters such as, body mass, step length, step width, pacing rate, etc., that justifies the use of a correlation matrix (Toso et al. [3]).

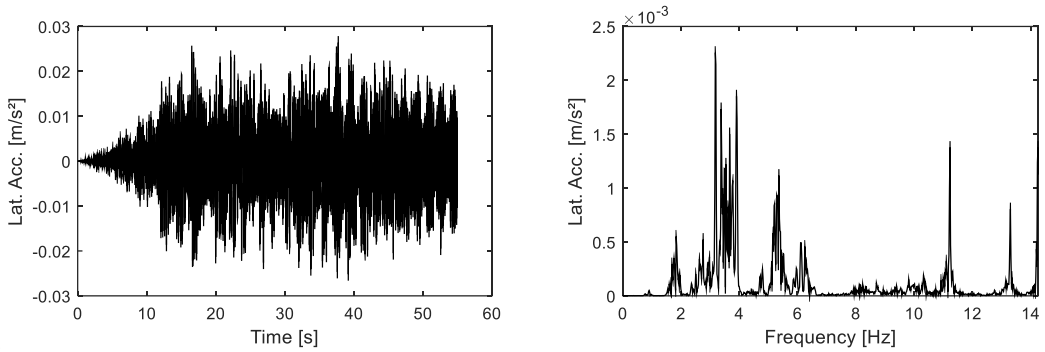
Figure 4 presents the results of the mid-span accelerations in the longitudinal, vertical and lateral directions. This numerical simulation uses the Biodynamic Synchronized Coupled Model (BSCM). This model is couple to the structure in the vertical degree of freedom. In other directions remaining the fully synchronized force model. This analysis assumes that the three force components are completely synchronized (time and space), and uses the kinetic and kinematic parameters for the pedestrians. A pedestrian crowd of 0.25 pedestrians/m^2 is use in this simulation.



(a)



(b)

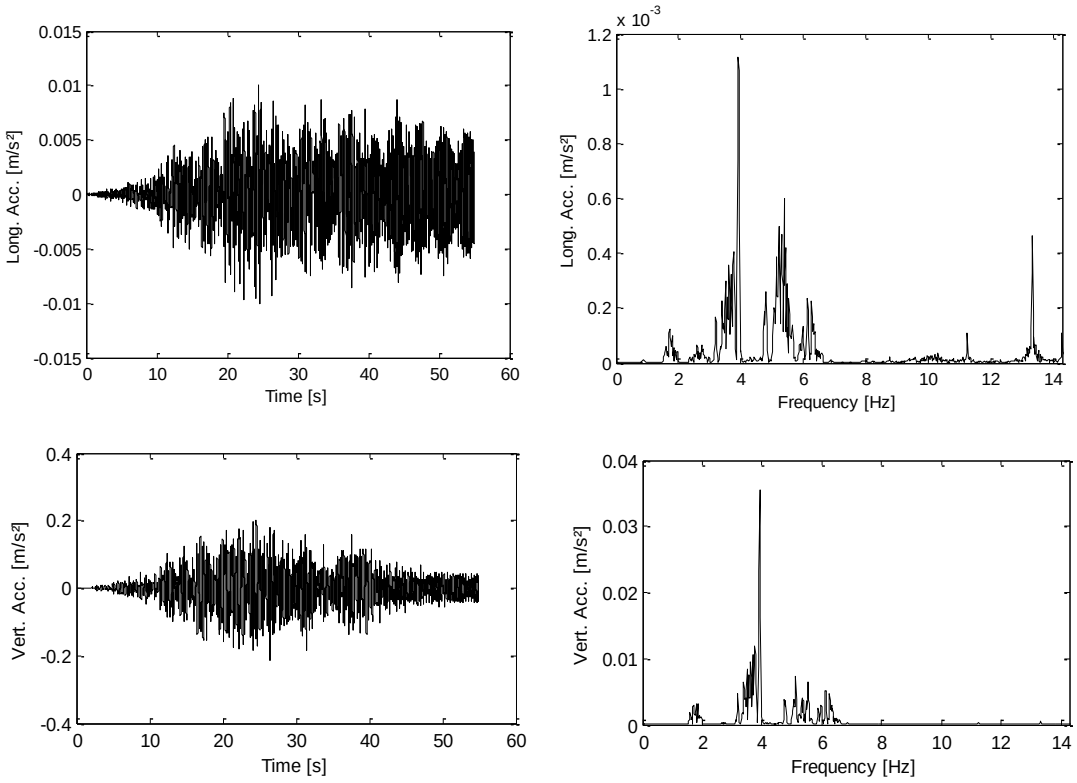


(c)

Figure 4. Acceleration response for BSCM and crowd density 0.25 ped/m²:

a) longitudinal, b) vertical and c) lateral directions.

Figure 5 shows the results of mid-span acceleration for longitudinal, vertical and lateral direction, considering just the Fully Synchronized Force Model (FSFM) in three directions. As in the previous example, there is no synchronism between pedestrians, that have their own pacing rates, and crosses the footbridge only once.



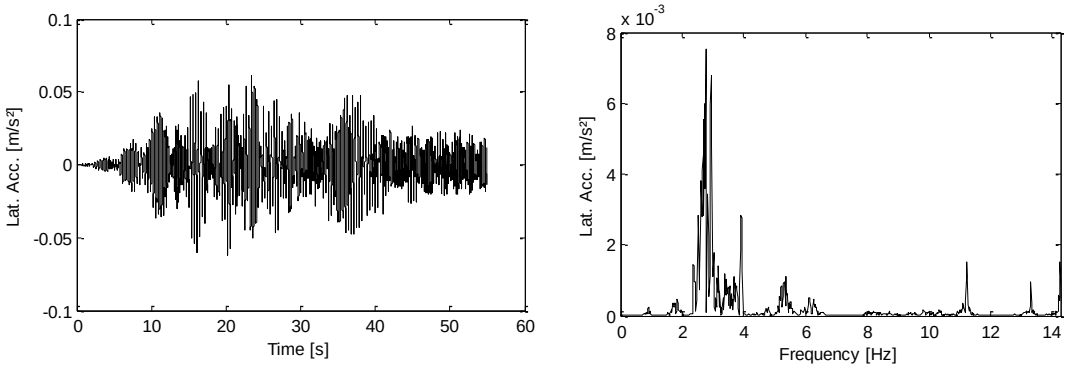


Figure 5. Acceleration response for FSFM and crowd density 0.25 ped/m^2:

a) longitudinal; b) vertical; c) lateral direction.

The numerical results presented in Figures 4 and 5 shows natural frequencies to around 2.0 Hz. These frequencies are associated with pedestrians' pacing rates. A frequency about 3.91 Hz corresponds to the natural frequency of the first vertical bending mode of the structure that was excited by the pedestrian crowd. Furthermore, the fundamental frequency of the structure (frequency about 3.0 Hz which corresponds to the lateral bending mode) was also excited by the pedestrian crowd, using both models. Considering the lateral and longitudinal directions the previous results shows frequencies around 11.0 and 13.0 Hz. These frequencies are excited due to the presence of the pedestrian thrust and deceleration phases in the human step and the zig-zag pattern in the force application. These frequencies are not excited if Design Codes (simplified force models) are used, because Design Codes assumes that the forces acting in a straight line along the direction of walking at a constant speed. Furthermore, the torsional mode (6.20 Hz) was also excited using both models, due to the spatiality of application of the pedestrian load that produces torsion in the footbridge. These frequencies, again, will not appear if simplified force models be used, since this model assumes the application of the load along a straight line.

Table 1 shows the RMS acceleration (footbridge's mid-span response) obtained with the two models (FSFM and BSCM). The acceleration was obtained in longitudinal, vertical and lateral directions. These results show BSCM presented lower acceleration values than FSFM in all directions.

Table 1. RMS acceleration response for a density of 0.25 pedestrians/m^2.

	RMS mid-span acceleration (m/s^2)		
Model	Longitudinal	Vertical	Lateral
FSFM	0.0026	0.0526	0.0158

BSCM	0.0019	0.0394	0.0070

* FSFM: Fully Synchronized Force model; BSCM: Biodynamic Synchronized Coupled Model.

Regarding the influence of the BSCM, considering a crowd density of 0.25 ped./m^2, it is noted that both models (Biodynamic Synchronized Coupled Model and Fully Synchronized Force model) presented a fundamental frequency about 3.91 Hz, i.e., there was no modification in the structural fundamental frequency. Additional simulations (Table 2) show that for the crowd density of 0.50 and 0.75 ped./m^2 the use of FSFM still results in structural fundamental frequencies at 3.91 Hz, as expected. However, the BSCM presents a decrease in the structural fundamental frequency, according to Table 2, proving the previous trend. It is concluded that this is due to increase in overall mass as the crowd density increases. Maybe such decrease in natural frequency was not observed in a crowd density of 0.25 ped./m^2 due to a low number of pedestrians.

Table 2. Structural fundamental frequency (Hz).

	Crowd Density (ped./m^2)		
Model	0.25	0.50	0.75
FSFM	3.91	3.91	3.91
BSCM	3.91	3.61	3.47

* FSFM: Fully Synchronized Force model; BSCM: Biodynamic Synchronized Coupled Model.

4.2 Experimental results

The results presented in Figure 6 correspond to the investigated pedestrian density (0.25 ped./m^2). In a previous publication, Brito et al. [20] measured the vertical acceleration of this footbridge at the mid-span. In this case and crowd density, the subjects crossed the structure freely, maintaining their own pacing rates.

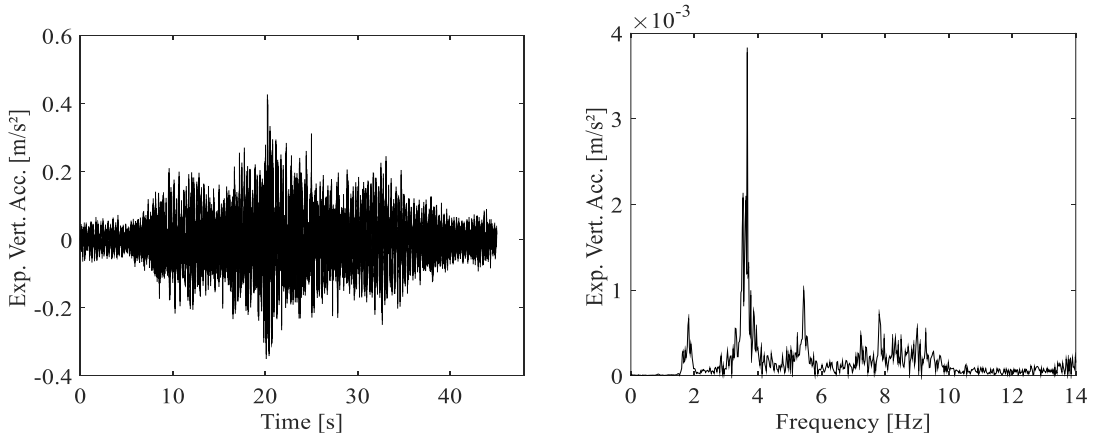


Figure 6. Mid-span vertical acceleration: experimental measurement (0.25 ped./m^2).

Both models BSCM and FSFM presents a similar shape for the vertical acceleration. The results for BSCM from Figure 4(b) shows a peak acceleration of 0.15 m/s^2. Using the FSFM (Figure 5b) the acceleration peaks are 0.20 m/s^2 and the experimental values are about 0.40 m/s^2. One can note that these numerical results are underestimating actual peak vibration. In terms of vertical RMS acceleration, the values became closer to the experimental ones (0.068 m/s^2), with FSFM resulting in 0.0523 m/s^2 and BSCM 0.0394 m/s^2. It should be emphasized that this comparison was harmed because most of the BSCM parameters were not available and the experimental campaign was performed previous to the development of the BSCM.

Figure 7 shows the spectrogram for the corresponding mid-span vertical acceleration: experimental measurement. This shows how the natural frequency varies along time according to the mass variation due to crowd flow. One can notice that the main lower frequency only happens during the crowd entrance in the footbridge (approximately from 6 s to 35 s). The second main frequency happens along all the experiment.

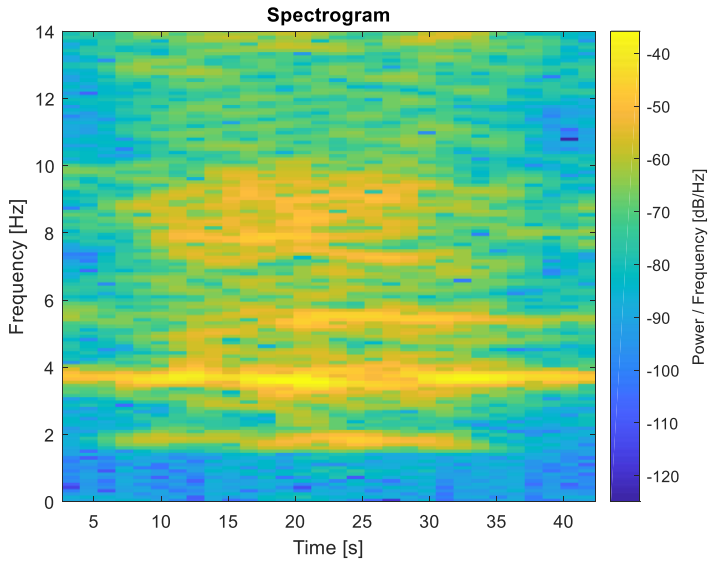


Figure 7. Spectrogram for the mid-span vertical acceleration: experimental measurement (0.25 ped./m^2).

Conclusions

In this paper, it is used a biodynamic model with synchronization of the three force components in space and in time with a stiffness-mass-damper model coupled with the structure's FEM to assess the pedestrian structure interaction. Both models used here (Biodynamic Synchronized Coupled Model and Fully Synchronized Force Model underestimated the peak vertical acceleration values when compared to the experimental ones and this suggest other sources of uncertainty may affect the final

behavior. The effect of the BSCM in other simulation for higher crowd densities (0.50 and 0.75 ped./m^2) could be noticed since the simulated structure presented modifications in the dynamic behaviour as a decrease in first natural frequency and increase in the overall damping as the crowd density increases. This suggests the human body effectively dissipates part of this vibration energy. The results of the dynamic analysis using FSFM rendered larger RMS accelerations, mainly in the lateral and longitudinal direction if compared with the BSCM. Additional frequencies present in both spectral acceleration in the lateral and longitudinal directions can be attributed to the use of the synchronized force model, used in both models. The observed differences in spectral accelerations in the vertical direction are attributed to the biodynamic effect that is present in BSCM and not in the FSFM.

Regarding to natural frequencies of footbridge, the vertical fundamental frequency of 3.91 Hz was identified experimentally and numerically. This is a relatively high frequency when considering structures with similar spans according to CEB [21]. Possibly, this characteristic is a consequence of the balance of stiffness and mass obtained when using a composite footbridge (steel truss and concrete floor). Such characteristics are desirable, avoiding that the structural fundamental frequency be a value close to the frequencies of excitation of the first harmonic of the pedestrian walking. Considering the lateral fundamental frequency, experimentally, the frequency of 3.12 Hz was obtained. This value is far from the frequency range considered to be critical, which are values close to 1.0 Hz. As for the vertical structural acceleration, the footbridge has vibration amplitudes below the values set by standards for comfort limits, which are of the order of 0.5 to 0.7 m / s^2 (OHBDC [22]; BS-5400 [23]; Eurocode 5 [24] and SETRA Guideline [11]). Numerically, it was observed that the excitation range of the second harmonic, excited by some pedestrians, are frequency values very close to the vertical structural fundamental frequency. However, the results of numerical simulations with different pedestrian's densities, walking on the footbridge indicate that it is not subject to excessive vibrations.

References

[1] Dallard P, Fitzpatrick AJ, Flint A, Le Bourva S, Low A, Ridsdill-Smith RM, et al. The London millennium footbridge. J Struct Eng 2001; 79 (22), 17-33.

[2] ISO 2631-2. International Organization for Standardization. Evaluation of human exposure to whole-body vibration, Part 2: human exposure to continuous and shockinduced vibrations in buildings (1 to 80 Hz), 1989.

[3] Toso MA, Gomes HM, de Brito JLV. Crowd-structure interaction: investigating the spatiality and synchronization of a pedestrian force model. Int J Constr Steel Res 2017;133: 510-21.

[4] Toso MA, Gomes HM. A coupled biodynamic model for crowd-footbridge interaction. Engineering Structures 2018; 177: 47-60.

[5] Zivanovic S, Pavic A, Reynolds P. Vibration serviceability of footbridges under human-induced excitation: a literature review. J Sound Vib 2005; 279: 1-74.

[6] Stoyanoff S, Hunter M. Footbridges: Pedestrian induced vibrations. Rowan Williams Davies and Irwin Inc, Ontario, Canada, 2003.

[7] Bodgi J, Erlicher S, Argoul P. Lateral vibration of footbridges under crowd-loading: Continuous crowd modeling approach. Key Engineering Materials 2009; 347, 685-690.

[8] Wheeler JE. Prediction and Control of Pedestrian Induced Vibration in Footbridges. J Structural Division 1982; 108, n° ST9, 2045-2065.

[9] Qin JW, Law SS, Yang QS, Yang N. Pedestrian-bridge dynamic interaction, including human participation. J. Sound Vib 2013; 332, 1107-1124.

[10] Tubino F. Probabilistic assessment of the dynamic interaction between multiple pedestrians and vertical vibrations of footbridges. J Sound Vib 2018; 417:80–96.

[11] SETRA-Service d'Études techniques des routes et autoroutes. Footbridges. Assessment of vibrational behaviour of footbridges under pedestrian loading, 2006.

[12] ISO 10137, International Organization for Standardization. Bases for Design of Structures-Serviceability of Buildings and Walkways against Vibrations, 2012.

[13] Harper FC. The mechanics of walking. Research Applied in Industry 1962; 15 (1), 23-28.

[14] Galbraith FW, Barton MV. Ground loading from footsteps. Journal of the Acoustic Society of America 1970; 48,1288-1292.

[15] Blanchard J, Davies BL, Smith JW. Design criteria and analysis for dynamic loading of footbridges. In: Proceedings of the DOE and DOT TRRL Symposium on Dynamic Behaviour of Bridges, Crowthorne, England, 1977, 90-106.

[16] Kerr SC. Human Induced Loading on Staircases. PhD Thesis (Mechanical Engineering Department) University College London, London, 1998.

[17] Bathe KJ. Finite element procedures. 2nd ed. New Jersey: Prentice-Hall; 1996.

[18] Brasiliano A, Doz G, Brito JLV, Pimentel RL. Role of non-metallic components on the dynamic behaviour of composite footbridges. In: Proceedings of the 3rd international conference footbridge; 2008.

[19] Toso MA, Gomes HM, da Silva FT, Pimentel RL. Experimentally fitted biodynamic models for pedestrian-structure interaction in walking situations. Int J Mech Syst Signal Process 2016; 72-73: 590-606.

[20] Brito JLV, Doz GN, Ávila SM, Pimentel RL, Brasiliano A, Roitman N, et al. Evaluation of the dynamic behaviour of a composite footbridge located in the city of
Brasília-Brazil. In: XXXIV Jornadas Sul Americanas de Engenharia Estrutural; 2010
[in Portuguese].

[21] CEB, Comite Euro-International Du Beton. Bulletin D'Information N° 209. Vibrations Problems in Structures. Practical Guidelines, Lausanne, Switzerland, August, 1991.

[22] OHBDC, Ontario Highway Bridge Design Code, Highway Engineering Division, Ministry of Transportation and Communication, Ontario, Canada, 1991.

[23] BS 5400, British Standards Association. Steel, Concrete and Composite Bridges - Part 2: Specification for Loads; Appendix C: Vibration Serviceability Requirements for Foot and Cycle Track Bridges, London, 1978.

[24] EUROCODE 5-2. Design of Timber Structures – Part 2: Bridges, ENV 1995-2, European Committee for Standardization, Brussels, Belgium, 1997.

ISSN 2601-8683 (Print)
ISSN 2601-8675 (Online)
European Journal of
Formal Sciences and Engineering
January - June 2020
Volume 3, Issue 1

The Dimensional Stability and Durability of Acrylic Resins for the Injection of Cementitious Systems

C. S. Paglia

University of Applied Sciences of Southern Switzerland, DACD,
Institute of Materials and Constructions, Trevano, Canobbio, Switzerland

A. Krattiger

Drytech SA, Impermeabilizzazioni,
via Industrie, Bedano, Switzerland,

Abstract

The dimensional stability and durability of Acrylamide- and Methacrylate-based acrylic resins have been studied. The dimensional stability was characterized by measuring the volume expansion of samples immersed in water for a period up to 240 days or by exposing the samples to 23°C and 50 %, 90 % relative humidity and by monitoring the shrinkage. The durability was investigated by exposing the resins to cyclic variations of temperature in air and in water. The resins generally exhibit a significant volume change up to 160 % of the initial volume when immersed in water or exposed to a relatively dry atmosphere (23°C and 50 %). A general increase in the material stiffness and/or crack formation on the surface of the resin is observed. On a long-term basis, the durability of the resins may significantly vary with occasionally a partial or complete deterioration of the some resins. A general better dimensional stability and durability is observed for the Methacrylate-based resins as compared to the Acrylamide-based resins.

Keywords: dimensional stability, durability, acrylic resins, injection

Introduction

Injection grouts are extensively used in the construction field for above- and underground applications, in particular to stabilize or strengthen soils or weak materials or to increase the water tightness of structures. The most common grout materials are cement-based. In the recent years, the rapid development of the material technology in the cementitious field, promoted the use of ultrafine and special cements and the addition of different materials such as filler and additives to the cement-based mixtures [1]. The advent of chemical additives significantly changed and improved the properties of the fresh and hardened injection materials. Superplasticizers [2], accelerators, air entertaining agents and other additives and in general polymer modified cementitious

materials [3] significantly improved the properties of the injected mixtures. Among the different types of injection systems [1-3], polymer modified gouts, i.e. latex modified, appear to promote an increase in tensile and flexural strength, thus improving the cement-aggregate bond [4, 5].

To reduce or stop the water loss throughout a structure, acrylic resins are also used as one of the main injection materials. In this concern, modified grouts consisting of cement, clay, water, acrylic resins or methyl methacrylate co-polymer emulsions were recently investigated [6]. The addition of latexes improved, among other properties, the compressive strength, the shear bond strength and the resistance to wet-dry cycles [6]. Nevertheless, a lack of information exists on the dimensional stability and on the long-term behaviour of acrylic resins used as injection system in cementitious material.

The goal of this work is to study the dimensional stability and durability of different types of commercially available acrylic resins used to restore the water tightness of concrete structures.

Experimental

The acrylic resins either acrylamide or metacrylate – based, consisted of two main components. The single components prepared with the additive, were supplied ready to mix, in most of the cases, or required additional mixing according the mix proportions on the resin data sheets provided by the suppliers. The single components were then simultaneously mixed and poured in cylindrical plastic mould with a diameter of 5 cm.

RESIN	TYP OF RESIN
Resina A	Acrylamide-based resin 1 Components A, B – Producer 1
Resina B	Acrylamide-based resin 2 Components A, B – Producer 1
Resina C	Methacrylate-based resin 1 Components A, B – Producer 1
Resina D	Methacrylate-based resin 2 Components A, B – Producer 2
Resina E	Methacrylate-based resin 3 Components A, B – Producer 3
Resina F	Methacrylate-based resin 4 Components A, A” Component A* Component B Component B’ – Producer 3

Table 1. Type of acylic resins.

The dimensional stability of the resins during the time, in particular after water storage, was investigated by alternatively weightening the samples in air and in water followed by the calculation of the volume change similarly as described in the norm EN 14498 [7].

Three samples for each type of resin were measured. The dimensional change with time caused by the storage of the resins in a dry atmosphere (23°C and 50 % relative humidity) and in a water semi-saturated atmosphere (23°C and relative humidity > 90 %) was studied by measuring the shrinkage. The measurements were carried out for both atmosphere on two samples pro type of resin. The shrinkage was measured by placing the cylindrical plastic moulds on a metal plate and controlling the vertical length change with a length comparator. In this concern the measuring procedure was taken from the norm EN 12637-3, even though the measurements concerned the shrinkage [8].

The durability tests were carried out according to the norm EN 13687-3 with the following exposure conditions: 2 hours in water at 21°C ± 2°C, 4 hours in air at – 15°C ± 2°C, 2 hours in water at 21°C ± 2°C and 16 hours in air at 60°C ± 2°C [9]. In this concern, the visual aspect and the mass loss after the cycles were examined on three different samples pro type of resin.

Results and Discussion

The dimensional stability

The acrylic resins own their capability of sealing cracks to the volume expansion when in contact with water. Most of the investigated resins immersed in water exhibit a relatively rapid increase in the volume during the first 30 days. Afterwards the expansion levels off until 240 days. The volume remains relatively constant on a long-term basis for the resins E, F /AII + B, F /AII+BI, F/A+BI, A and C, while the resin D exhibits a volume decrease (Fig. 1 A). On the other hand, the resins F/A*+BI, F/A*+B and B, exhibit a continuous increase in the volume during time up to 200-250 % of the initial volume (Fig. 1A). A detail investigation at a early stage up to 30 days indicates a relatively limited volume increase for the resins C, F/A+BI and A as compared to the other resins (Fig. 1 B). The latter resins also exhibit a reduced increase in the volume on a long-term basis (Fig. 1A).

The resins exhibit a relatively high shrinkage in a dry atmosphere up to 30 days. The shrinkage values vary from 100 % up to 160 % (Fig. 2A). In a more water saturated atmosphere (23 °C / > 90 % relative humidity), the shrinkage up to 30 days is reduced for most of the resins to values around 5 %. Only the resin E reaches values up to 20 % (Fig. 2 B). Resins such as for instance F/A*+B, which exhibits a high volume expansion when immersed in water, indicates a general reduced shrinkage. That means, only a slight general correlation exists between the capability of the resins to adsorb water, i.e volume expansion, and the shrinkage.

Interestingly the different type of resins used in this study, i.e. Acrylamide or Methacrylate-based, exhibit a significant difference in the capability of adsorbing water and shrinkage. This significant difference in the stability is also observed within the Acrylamide or Methacrylate-based groups.

A visual inspection indicates that the resins immersed in water relatively maintain their original stiffness, except for the samples E and F/A*+B, where a significant reduction of stiffness is observed (Fig. 3-7). A significant colour change after immersion in water is observed for the resins B, C, D, F/A*+BI, F/A+BI, F/AII+BI. The resins subjected to shrinkage in a dry atmosphere do not generally exhibit a significant change in the colour. Nevertheless some resins, in particular the samples A and C exhibit the formation of cracks, and the resin E indicates a reduction in the stiffness (Fig. 3-7).

The durability

The durability of the resins investigated by cyclic exposure to different temperatures has been evaluated by visual inspections and by measuring the mass loss. The resins A, (Fig. 3), C (Fig. 4), E (Fig. 5) exhibit a significant deterioration after 24 cycles of exposure. The other samples (resins B, D, F/A*+B, F/A*+BI, F/AII+B, F/AII+BI) exhibit a general shrinkage as compared to the reference samples (Figs. 3-7). A general increase in the stiffness as compared to the reference samples is also observed for this latter resins and occasionally, small surface cracks are observed for the resins B, D, F/AII+BI, F/A*+B, F/A*+BI. Most of the resins exhibit a significant mass loss after 6 cycles of exposure (Fig. 8). In this concern, the main loss of mass is present at a early stage, while on a later stage, the mass loss is largely reduced. The resin A exhibit a decreased mass loss at a early stage, but at a later stage, the mass loss is large and the resin is almost completely deteriorated.

General remarks

Generally it can be stated that, the formation of small cracks during shrinkage or the partial deterioration of some resins after the durability tests cannot be directly correlated with a performance decrease in terms of sealing cracks in cementitious systems. Nevertheless, the advanced stage of deterioration, in particular for the resins A and C after the durability tests, makes this performance largely questionable. Furthermore, the volume expansion of the resins when in contact with water should be limited. A unlimited expansion within the cracks may cause an increase of pressure within the cracks, which may reduce the sealing performance of the resins.

Thus, the general dimensional stability of the resins, in terms of a controlled volume change when the resins are in contact with water or exposed to a dry atmosphere, appear to be generally high for the methacrylate-based resins D, F/A+BI, F/AII+B, F/AII+BI. Concerning the capability to withstand cyclic exposures to different temperatures in air and in water, these latter resins (except the resin F/A+BI, which exhibits an increased deterioration) exhibit a very limited deterioration.

On the other hand, the acrylamide-based (acrylamide: carcinogenic component) resins A and B exhibit a general reduced dimensional stability and durability, in particular with respect to the resistance to the cyclic exposure to the climatic conditions, to the cracks

formation within the resin during shrinkage (resin A), and to the expansion of the resin when in contact with water (resin B).

Conclusions

The resins in contact with water exhibit a relatively rapid volume increase within the first 30 days, which in some cases reach 160 % of the initial volume. Similar volume reductions are observed when the resins are exposed to a dry atmosphere.

The volume changes are occasionally associated with a change in the stiffness and/or the formation of surface cracks on the resins.

The cyclic exposure to different temperatures in air and in water may cause a general increase in the stiffness of the resins and in some cases an almost complete deterioration.

The Methacrylate-based resins exhibit a general higher dimensional stability and durability as compared to the Acrylamide-based resins.

Acknowledgements

The authors would like to thank E. Pesenti, S. Antonietti and R. Bucellari of the Institute of Materials and Constructions for the technical support.

References

[1] Shroff, A. V. and D. L. Shah, Grouting Technology in Tunneling and Dam Construction, 2nd Edition, A. A. Balkema Rotterdam Brookfield, 1999.

[2] Bremen R., The Use of Additives in Cement Grouts, Hydropower & Dams, Issue one, 1997, pp. 71-76.

[3] Ohama Y., Polymer-modified Mortars and Concretes, Ramanchandran VS Editor, Concrete Admixtures Handbook: Properties, Scince and Technology, Park Ridge NJ, USA, Noyes, 1984, pp. 337-422.

[4] Afridi U. M. K., Z. U. Chaudhary, Y. Ohama, K. Depura and M. Z. Iqbal, Strength and Elastic properties of Powered and Acqueous Polymer-modified Mortars, Cement and Concrete Research, 24, 7, 1994, pp. 1199-1213.

[5] Anagnostopoulus C. A., Anagnostopoulus A. C., Polymer-cement Mortars for Repairing Ancient Masonries: Mechanical Properties, Construction and Building Materials, 16, 7, 2002, pp. 379-384.

[6] Anagnostopoulus C. A., Cement-clay Gouts Modified with Acrylic Resin or Methyl Metahacrylate Ester: Physical and Mechanical Properties, Construction and Building Materials, 21, 2007, pp. 252-257.

[7] EN 14498, Products and Systems for the Protection and Repair of Concrete Structures – Test Methods, Volume and Weight Changes of Injection Products after Air Drying and Water Storage Cycles, 01.01.2005.

[8] EN 12637-3, Products and Systems for the Protection and Repair of Concrete Structures – Test Methods – Compatibility of Injection Products – Part 3: Effect of Injection Products on Elastomers, 01.01.2005.

[9] EN 13687-3, Products and Systems for the Protection and Repair of Concrete Structures – Test Methods – Determination of Thermal Compatibility, Thermal Cycling without De-icing Salt Impact, 01.04. 2003.

ISSN 2601-8683 (Print)
ISSN 2601-8675 (Online)
European Journal of
Formal Sciences and Engineering
January - June 2020
Volume 3, Issue 1

Requalification of Residential Space in Tirana - Methodologies and Intervention Strategies

Etleva Dobjani

Arch. PhD, University POLIS, Tirana, Albania

Abstract

The city of Tirana is subject to constant physical and spatial metamorphosis. In its urban territory, the different residential typologies are well distinguished by socio-economic conditions and the technical-constructive characteristics which have been influenced by political development of the country. The multi-family residential buildings from the post-war period up to the 1990s, in addition to the problems that accompanied them from their initial construction, are found today in front of a physical degradation derived from the years they have. Problematic residential spaces are also most of the buildings constructed in the first decade after 1990, characterized by a low technological and housing quality, derived from an uncontrolled and informal development of the building sector. The building quality in this research, is focused on the applied architectural standards, the technological solutions adopted and the energy consumption derived from them. From the analysis made it has been reached in the conclusions that a renewal and requalification process is necessary to reduce the energy waste and to increase the quality of housing within residential spaces. The main objective of this research is to contribute to the sustainable development of the residential area of Tirana, referring to both the architectural and technological scale. Sustainable development in this paper is closely linked to the quality of residential spaces, which is directly related to the quality of life of the inhabitants. Due to the complexity of the urban environment and its transformations over time, the identification of light regeneration and redevelopment strategies is fundamental, minimizing demolition works. This article includes numerous European examples and a theoretical part, from which proposals for the future development of the residential areas of the city of Tirana can be extrapolated.

Keywords: Requalification, regeneration strategies, sustainable development, residential space, energy efficiency

Introduction

The vast stock of multifamily residential buildings in Tirana is very dynamic. A part of this building stock is inherited from the regime period that means that they have fulfilled their life cycle of 50 years or that they're near to this process. Another part of the building stock has been constructed in the first years of 90s and for more than 15 years, the buildings were raised in a turbulent political situation that led to the poor quality of buildings in terms of their technology and energy efficiency parameters. Due to these phenomena renovation and requalification is needed in order to respect new energy savings in the buildings and to create more qualitative living spaces. Over the last decade, some improvements are made in this field, but there is nevertheless much to do in this area. It is valuable to find through the research some possible strategies for its future development.

The objective of this research is the definition of some possible interventions in order to improve the residential living spaces in Tirana neighborhoods. Due to the complexity of the urban environment and its transformations in time, the urban regeneration processes are the subject of an urban and architectural multi-scale study. The strategy proposals will be in this paper both in the architecture scale and in small scales accompanied with technology details. By defining some requalification strategies inside the existing urban pattern, some sustainable strategies for future development residential forms can come up, in order to be applicable in the analogue existing residential neighborhoods or in the new one. The sustainable development is here linked with the quality of the living spaces, which is closely linked to the quality of life of the inhabitants in these spaces.

Being in an existing urban pattern, drastic changes cannot be done and regeneration strategies can be identified in situ. Regeneration concept has been used from two centuries up to now in Europe but it is still an un-explored and a very new concept in Albania and in Balkans. In England, Germany, Netherland, France etc, there are projects applied in different social neighborhoods or peripheral ones and many academic studies has been conducted in Italy regarding to this topic. Important reference book has been used here as, "*Rigenerare le aree periferiche*" of A. de Cesaris and D. Mandolesi; "*Linee guida per la riqualificazione dei quartieri innovative nell'Italia centromeridionale*" edited by F. Dematteis and B. Todaro; *Sustainable design. A Critical Guide, Princeton Architectural Press,* D. Bergman, (2012); *The building envelope. Applications of new technology cladding,* Brookes, A. J., Grech, Ch.; the collection of researches in *A HANDBOOK OF SUSTAINABLE BUILDING DESIGN AND ENGINEERING. An Integrated Approach to Energy, Health and Operational Performance,* edited by D. Mumovic and M. Santamouris, etc.

Existing Buildings Structure

Various constructive and technological systems of the buildings before '90 and their conditions today

Residential neighborhods with multifamily houses started to be constructed in Tirana in the 1940s. The first buildings were constructed by italians as the 'Aeronautics buildings", "La casa degli impiegati", "Blloku Miqesia", etc. After the first years of forties, with the political regime changes new building strategy were applyed. New neighborhoods of residential blocks raised up. Some of them are *50 Vjetori*, *1 Maji*, *Shallvaret*, *21 Dhjetori*, etc. After 1945, in Albania, as in other countries of East Europe, was a centralized economy and a constraint city planning. In this period there, follows a reconstruction post war process and an urban evolution based on the principles of the *modern architecture.*[1] *«The modern architecture was never officially accepted by the regime of the Albanian state and it was secretly smuggled by the architects. Modern buildings were constructed not only in Tirana like Hotel Tirana (V. Pistoli), Flora residence (arch. M.Pepa and arch. I.Prushi), those in Dibra street (arch. M.Velo) but also in the city of Korça (arch. P. Kolevica) or in the buildings constructed in the residence center of Shkodra, etc.»*[2] Elements of traditional or classical architecture were substituted by pure forms and volumes. This was particularly noted not only in the residential areas, but also in the administrative and tertiary buildings.

The first '*social realism' buildings* in Albania realized in classical style were mainly inspired by the Russian Academy which itself is based on ancient Greek style, Roman Renaissance architecture and European neoclassicism. Some social, administrative and cultural buildings which belongs to this category are Kinostudio, the Ministry of Internal Affairs, residential buildings in Kombinati i Tekstileve "Lenin", the Lenin-Stalin museum, the Central Comity of the Albanian Communist Party, the theater of Shkoder, *the Parliament in Tirana*,[3] Shallvare palaces, Agimi palaces (arch. A. Strazimiri), etc. The architecture language of these buildings facades was a mix between classic European elements and local architecture elements.

After these first constructions in the end of fifties and the beginning of sixties due to the weakening of relations between Albania and the Soviet Union, having also a low economic level in the country, the architecture itself was oriented through certain standards that guaranteed minor costs of their constructions. The key factor of this '*new trend era*' was the influence of many architects that had studied abroad: in Poland (Enver Faja, Vasilica Silco), Bulgaria (Valentina Pistoli), Hungary (Mergim Çano), Romania

[1] *The modern influence in Albania was clearly seen in the architecture of Albanian architects such as Q. Butka, arch. S. Luarasi, arch. A. Lufi, E.* Faja, etc. Some administrative buildings in Tirana which can have elements of Modern architecture are the National Gallery of Arts, the National Historical Museum, etc

[2] Faja, E., *Gjeneza e Arkitekturës moderne dhe e realizmit socialist në Shqipëri, në vitet 1945-1980*, 16/12/2010 (in 55 Magazine Online, http://gazeta55.al/gjeneza-e-arkitektures-moderne-dhe-e-realizmit-socialist-ne-shqiperi-ne-vitet-1945-1980/)

[3] The foundations of the Albanian Parliament in Tirana were built based in the project of Bosio, but during the communist regime, the project was adapted according to the tendency of the time by the Albanian architect *Anton Lufi*.

(Kristaq Sahatçiu) and many others who brought many modern elements influencing the way that the projects were implemented. The classic trend of Russian Academy was left aside and the orientation was more on the modern *l'Existence Minimum.* An example of this new way of planning was the residence area in the "Miqesia" block. The local architecture art had to be free of any oriental influence and without any decoration elements. The architecture had to be functional, minimal and built for the masses usually using volunteering labor. The prisoners constructed the Agimi Palaces (in the end of 50's) through volunteering labor.

Architecture, as any other form of art, was developed through a strong control of the state. The projects were adjusted to the rules and approved by a very strict commission. The minimum standard of the apartment was 40-42 meter square, which included a number of four or five beds confirming the necessity to increase illumination and ventilation of each building. The control of the state in the architectonic development, actions against the western influences and the drastic reduction of the state investments led to poor architectonic solutions in terms of esthetics and quality. The development of the construction materials sector led to the standardization of buildings and their constant repetition through the entire city firstly with bricks and after 1965 with prefabricated panels. In this period, the four-five floor residential buildings were mostly developed. Analog plans were replicated through all the country. «The phenomenon of the standardization of the apartment space's design also included the standardization of dimensions and was called '*tipization*'. »[4] Consequently, in this way there were implemented standard coded projects (60.1; 60.2; 60.3 etc., referred to the years 1960, 70.1; 70.2 for the 70's and 80.1, 80.2 etc., for the 80's) used in all the new collective residential blocks. Rarely any modification would occur based on the exact location and in that case they had to be approved by the "the Central Comity"[5]. The construction material of the buildings in this period of time was realised with traditional brick walls of 38 cm and 25 cm for buildings of 3 and 4 floors and sometimes 50 cm in the first floors of the buildings with 5 and 6 storeys. The buildings were plastered in both sides mainly or only in the inside part. This technology was simple withoiut any exterior layer. Another construction typology was with concrete panel walls which was a technology coming from China. The concrete panels were ready to be installed in construction site and the plans were very rigid because of their construction typology, differently from the brick walls typology which allowed for greater flexibility. These multifamily buildings come today, after more than 40 years of life, with the need to repair facade elements, heating plants, doors and windows in order to improve indoor living conditions, minimize energy losses and improve aesthetic quality of the facades.

[4] Dobjani, E., Barandovski, I., Nelkovska, O., *Quality of life changes the quality of space*, Habitat 3, Tirana 2015, p.29

[5] The Central Comity in the Communist state is the term used to designate the most important political body of the state, directing the organization of congressional sessions and conducting deliberative functions electing the executive bodies. It takes on a greater relief over the parliament duties, which ratifies the decisions taken by the central committee.

Constructive and technological systems after '90s and the main problem issues

The city grew up from a single function to a multi-functional center and developed in vertical level and in horizontal too. The rapid urban growth and the lack of capacities of public control because of the political transitions, influenced in the creation of an irregular urban landscape and in the low quality of the residential space. The increasing demand for new homes, created an unpleasant situation of informal parasites interventions in the facades of the buildings, both existing and new ones. The intrusion of new volumes on the existing building facades and in the urban pattern, implies a critical situation due to the lack of open collective spaces and public services. Consequently, not only the quality of the building facades that surround the open space has deteriorated, but in the meantime there were also created low aesthetic, environmental, compositional, architectural and technological quality open spaces. The presence of informal and individual interventions in the facades, without homogeneous material, dimensions or colures, has created a diversified pattern creating so an uneven façade interrupting the façade continuity by punctual interventions.

Figure 1. Building constructed after '90. Facade degradation.

Figure 2. Building constructed before '90. Facade trasformation

The new buildings have different typologies: tower typology or linear typology. Usually more buildings volume are joint together creating long buildings with more than a hundred meters. The stairwells are mostly closed and their relationship with the public space is missing. The façade development follows a division between the base, the body and the building crown. The ground floor is intended for commercial functions. The upper floors are used for houses function repeating the plan on multiple levels. The top floor is the roof that usually houses a smaller housing plan, so a different typology.

The new buildings are built with load-bearing concrete structure (concrete beams and columns). The technology used for the building envelope is a very low quality. The exterior walls are made of 20 cm hollow bricks and in the most of the cases are only

plastered. This poor technology influences the low quality of life in the interior spaces of the house as a derivative of the great heat dispersions. The lack of thermoinsulation or the presenze of thermal bridges shows problems as mold and humidity inside the apartaments and plaster deterioration in the façade.

Requalification and regeneration strategies of residential building

Building adaptation with new requirements of nowadays

«If new buildings must respond to the changing needs of society, then we must also consider how to adapt the vastly greater number of existing buildings.»[6]

The urban fabrics are considered as organisms constantly evolving that should be changed and adapted to the new needs of contemporary life. As Rogers states in his book Cities for a small planet, new buildings as also existing ones should satisfy the daily needs of their inhabitants and their needs change over time. The permanent high demand in Tirana for new housings and the lack of government institutions control in the partly modification of the building volume by inhabitants, matching with their apartment position in facade, led to the chaotic development we have today in multifamily housing shells and urban shape. Furthermore, in Albania there is no normative framework that regulates individual informally interventions in façade and neither do we have any requalification program how to adapt existent buildings to the new needs of the residents. Related to all these observations, the regeneration strategies in Tirana buildings, are focused in the process of sustainable development, energy efficiency and life quality, identifying possible strategies of interventions. Some important issues of intervention have been identified referring to the building regeneration and envelope transformation in terms of energy efficiency.

The façade of the building is considered an important element that relates and divide the interior inhabited space of a building and the outside space. It is not only an important element because of its aesthetic function but is also an important element because of its function as a protection layer against outside weather conditions. It is important because of the comfort that should insure to the inside space. In the first Venice Architecture Biennale in 1980, with the title 'The presence of the past'directed by Paolo Portoghesi, the attention was brought toward the façade and among 13 other installations, Dardi participated with the installation of Strada Novissima. In his text, Behind The Façade, he see the facade «as a meeting layer between internal structure and urban dimension, filter and diaphragm, a layer that function as a fence between public space and private one and relates them.»[7]

[6] Rogers, R., *Cities for a small planet*, ed. by Philip Gumuchdjian Faber & Faber, 1997, p.79

[7] *Catalogo della I motsra Internazionale di Architettura, La Biennale di venezia, 1980* oggi in Costanzo, M., (a cura di) *Costantino Dardi. Architettura in forma di parole*, Macerata, Quodlibet, 2009, e in Giancotti, A., *Trasformare l'involucro. Conservazione e riscrittura dell'imagine nel patrimonio dell'edilizia residenziale pubblica*, in Todaro, B., De Matteis, F., (a cura di) *Interventi sull'abitare. Linee guida per la riqualificazione dei quartieri innovativi nell'Italia centromeridionale*, Propsettive Edizioni, Roma, 2012, p. 151

Germany, with sensitive policies towards the environment and energy saving, has organized during the past two decades, programs for restructuring and renewal operations to increase the quality of the internal space of the houses through improved thermal and acoustic performance by intervening in external envelope and improving the quality of the spaces in-between at the neighborhood level. The surgery helps retrain these neighborhoods and use new technologies or renewable materials.

In other post-socialist countries, as Serbia, Macedonia, Albania, etc., requalification programs have been missing totally. In Albania there are different laws related with the preservation of the "heat in the buildings" (Nr. 8937, date 12.9.2002) or the law on "approval rates, terms and conditions of design and construction, production and retention of heat in the buildings (DECISION no. 38 dated 16.1.2003), the LAW no. 9379, dated 28.4.2005, On energy efficiency or the Decision Nr.584, of 2.11.2000, on Energy savings and warmth keeping jobs, but these laws first of all have no "power" in the process of executive control in the field application leading to new buildings with low quality conditions; second, there is not any low related with the regeneration or requalification process of existing building stock constructed during the regime period.

A well-designed building enclosure, according to Magwood 2017, does four things: Keeps water out; Controls air flow into and out of the building; Keeps heat energy in or out, as desired; Manages vapor migration. A building that effectively controls water, air, heat, and vapor according to the demands of the climate and the needs of the occupant is a successful, comfortable, efficient, and durable building. Your basic understand of building science begins with identifying each of these four control layers in your building[8]

The current situation of the residential buildings in Tirana is categorized according to three construction periods, which also indicates their constructive character and façade quality:

_ Buildings constructed before 1944, which are mainly villas of one, two or three floors. Referring to INSTAT data, the stock of housing built before 1945, consists in 215 thousand apartments, mainly for individual family units, or more households, depending on the generation.

_ The period of the communist regime, from 1944-1990, led to the construction of public residential buildings, characterized by their height from three to six stores. During this period, only residential condominiums were built. The architectural and spatial composition of the condominiums and apartments was standardized in only a few typologies. Public residential buildings were owned by the state and were built with

[8] Magwood, Ch., (2017) *Essential Sustainable Home Design_ A Complete Guide to Goals, Options, and the Design Process*, New Society Publishers, pg. 62

public funds using very often the volunteer work. Referring to the INSTAT data in this period are built almost 450 thousand houses.

_ After nineties, in the first decade of the capitalist period, it prevails the construction of private houses in the suburbs of Tirana in comparison with residential buildings of 6-12 floors, more widely spread in the second decade.

Buildings constructed during this period, increased the density in the central urban areas and spread to the outskirts of the city, creating a current housing stock of poor technological quality and rigid architecture.

	Up to 1960	1961-1980	1981-1990	1991-2000	2001-2005	2006-2011	Inhabited buildings*	Non-inhabited buildings*	Total
Tirana	6,066	8,087	8,204	34,259	16,175	12,424	13,895	11,173	110,283

Figure 3. The quantity of multi-family residential buildings in Tirana in different periods after 1960. (font: INSTANT)

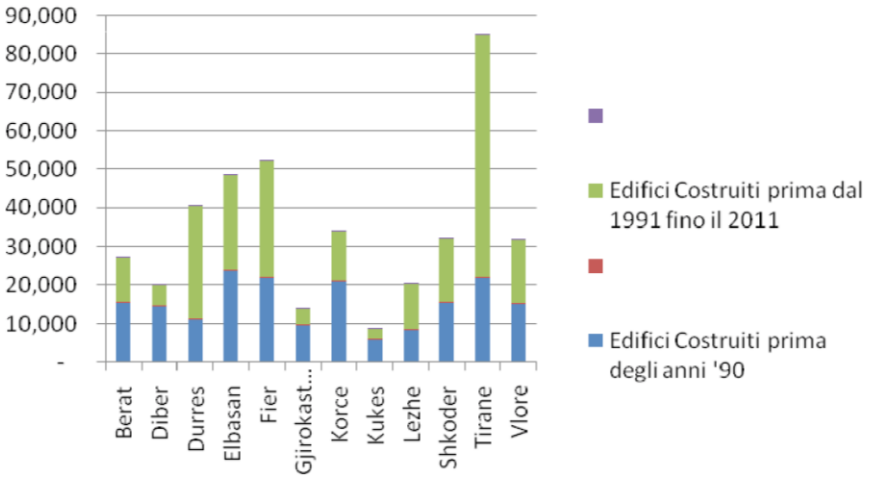


Figure 4. Edifici residenziali plurifamiliari costruiti prima e dopo gli anni '90 a Tirana. (fonte dei dati: INSTAT, grafica: l'autore)

Due to the low level of architectonic quality in houses and apartments, 25% of the total energy spent in Albania goes in residential sector. These parameters reflect on ways how to build and how the architects can improve the housing conditions. If regeneration and revitalization programs will be developed referring to the building envelope, the cost of energy for each housing unit, will be lower than the present. This intervention will improve consequently the thermal comfort inside the apartment, and at the same time will reduce the energy costs in the residential sector at the state level.

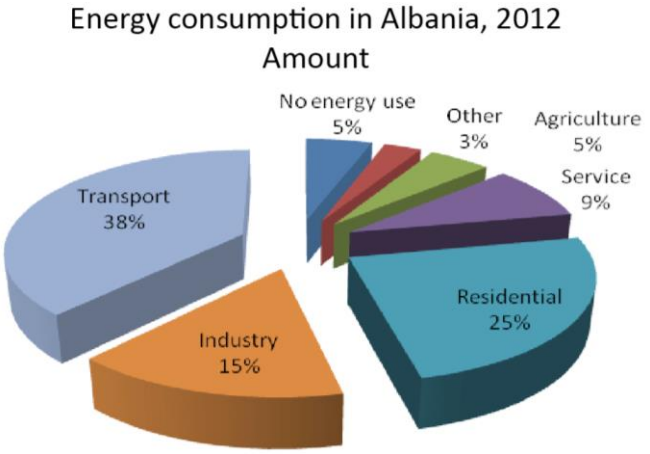


Figure 5. Energy consumption in Albania on various sectors, 2012. 25% of total budget goes for residential sector. (font: INSTANT)

As Rogers also states in his book Cities for a small planet, «the construction of our habitat continues to be dominated by market forces and short term financial imperatives. Not surprisingly, this has produced spectacularly chaotic results. It astounds me that the built environment in so many places remains an incidental political issue. »[9] This phenomenon is also very actual in Albania, because due to political change and the very long transition period the quality of residential spaces was very low. The total number of dwellings in Tirana in 2011, according to INSTAT data, is 1,012,400, and only 545.001 of these houses are in urban areas, the rest are rural housing. The biggest problems on the present situation of residential buildings, are their poor insulation of the walls and the roof, presence of thermal bridges and high energy consumption.

The current situation led to the necessity to improve the inside living conditions by improving the building facades or give suggestions for a residential building renewal. With all the efforts that Albania is making to join the European Communities, a very important area to invest in research is the new building stock, very problematic for its poor current conditions, which in 1950 will be considered at the end of their rehabilitation cycle (30-50 years).

Directive 2010/31 / EU requires all States Member or candidate countries to set minimum energy performance requirements for new and existing buildings, to ensure the energy certification and disciplinary controls on air conditioning systems and provides that, by 2021, all new buildings are "Nearly Zero Energy Buildings". State's Member should establish a national system of mandatory energy efficiency with the aims to achieve a cumulative goal of the final energy savings by 31 December 2020, at least 1.5% of the total energy sold to final consumers, for the period 2014-2020. These goals

[9] Rogers, R., *Cities for a small planet*, ed. by Philip Gumuchdjian Faber & Faber, 1997, p.17

are not fulfilled by Albanian development and a lot of investments should be done in this field in the architectonic and technological conditions of the house, in order to reduce energy costs and at the same time to increase the quality of the inside living conditions of the inhabitants. In recent years, Albania has taken important steps in the approval of energy efficiency laws in particular with Law No.124/2015 (Energy Efficiency Law) and Law No.116/2016 (Law on the Energy Performance of Buildings), which comply with Directive 2012/27/EU and Directive 2010/31/EU, respectively. The Albanian legislation has not yet defined the minimum requirements of envelope, plant solutions, including those using renewable energy sources for new buildings or energy refurbishment.

Are analyzed below two multifamily residential buildings in Tirana referring to their architectonic details and their energy consumptions. These buildings belong to different periods of construction.

The first one has four floors and has been constructed in 1959. It has a constructive systems made of with retaining brick walls. It is located near the Blloku area, in Abdyl Frasheri street and Wilson ring.

Figure 6. The first multifamily house location, taken as case study

The building analyzed is a multi-family residential building with two staircases from which access four apartments per each floor. It was initially designed for four floors and then a fifth floor was added over time. It has a depth of 9 meters, a length of 26 meters and a height of 16.6 meters, with a load-bearing brick structure of 25 centimeters in width.

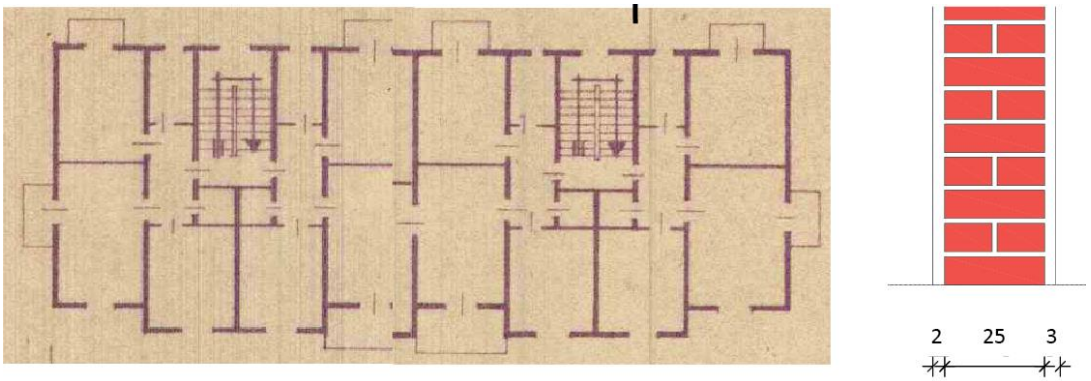


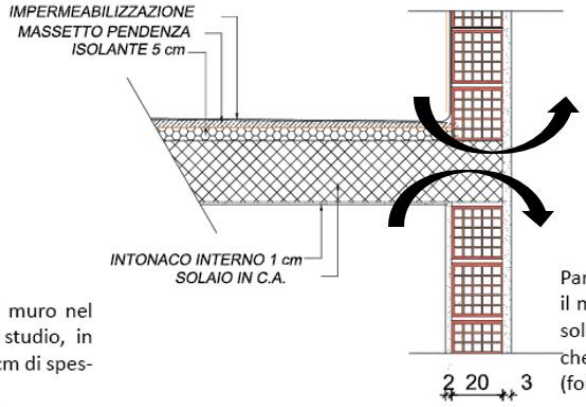
Figure 7. The first multifamily house plan and detail of the perimetral wall.

The second building has been constructed in the last two decades. It is a multifamily house designed for ten floors and it's located in a new neighborhood near Kombinat.

Figure 8. The second multifamily house taken as case study. Its location in the left and the plan in the right.

The building has been constructed in 2013. The type of building is an open U-shaped block with an internal courtyard. There are in total four stairwells from which four families enter per each floor. In total there are sixteen apartments per floor. It has a depth of 14.5 meters, a length of 37 meters and a height of 37 meters. The total area of the plant is 683 meters and the supporting structure is made with columns and beams in concrete material. The perimeter walls are 20 cm width, realized with hollow bricks and plastered in both outside and inside part.

Particolare del muro nel secondo caso studio, in laterizio di 20 cm di spessore.
(fonte: l'autore)



Particolare del nodo tra il muro perimetrale e la soletta dell'interpiano che crea ponti termici.
(fonte: l'autore)

Figure 9. Details of the perimetral wall and the node between the perimeter wall and the intermediate floor.

Possible interventions in the façade can be designed *adding a layer of thermal insulation; adding a layer of thermal insulation plus a layer of perforated bricks; making green facades, green roofs, and eliminate thermal bridges nodes.*

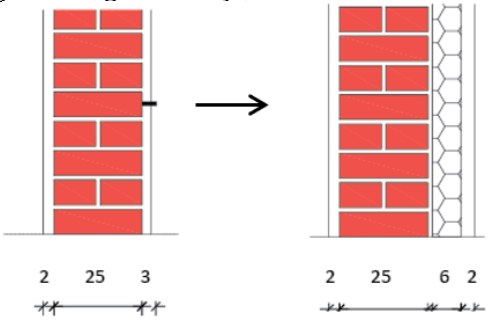


Figure 60. Possible interventions in the façade with traditional brick walls, by adding a layer of thermal insulation.

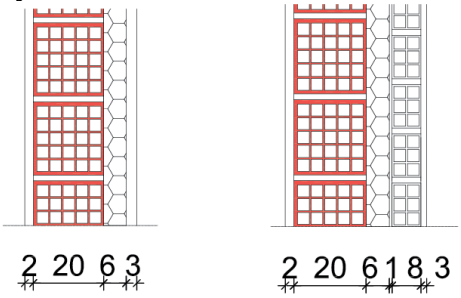


Figure 11. Possible interventions in the façade with hollow brick walls, by adding a layer of thermal insulation only, or a layer of thermal insulation plus a layer of external perforated bricks to improve thermal insulation of the external wall

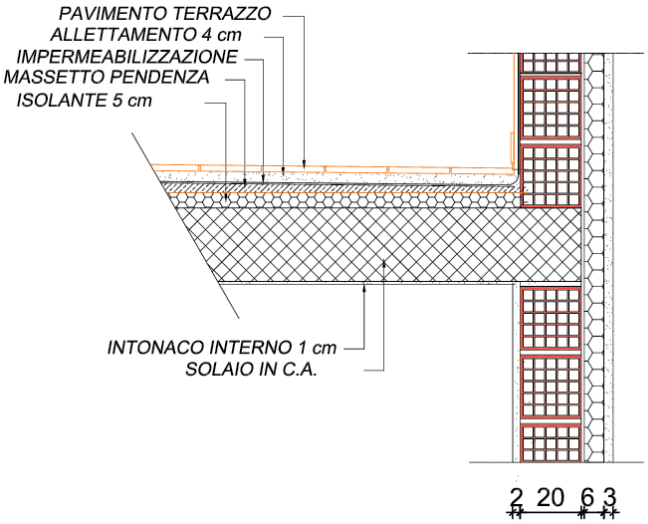


Figure 17. Possible interventions in the façade in order to eliminate the thermal bridges in problematic nodes.

Reconceptualization of the shell in residential buildings with new energy efficiency requirements

Energy Performance Calculations

The two buildings taken as a key study in the previous paragraph will be analyzed here by their physical state, such as the building width, length, height and the surface number of floors, the coefficient S / V ratio. After all these data, will be calculated the value of U (W/m^2K), thermal transmittance of the architectural elements as external wall, roof, floors and windows or external doors. Will be calculated also the building losses caused by various factors. These calculations help us understand how much each of these buildings is spending today on energy to heat the inner environment and how much energy will be spent after the regeneration interventions. The ratio between the total investments in regenerating facades interventions and the savings gives us the time of the return of the investment.

These calculations help us understand how we can intervene in existing buildings, how much time do we need for the return of the investment costs and the benefit in Euro that we have due to electricity costs for each family per year.

Case 1. Multifamily residential building constructed in 1959

No.	Case study	year of construction
1	Multifamily residential house	1959

Width	Length	Height	Floor Area	Volume	No. Floors	Envelope Area (5 facades)	S/V	Perimeter
[m]	[m]	[m]	[m2]	[m3]		[m2]		
9	26	16.6	234	3884.4	5	1362	0.06	70

Architectonic Element	Area	U	Tin - T out	Losses because of transimittion (Qt)	Thermal bridges (Qt)	Losses because of orientation (Qt)		Losses because of Infiltration	Qtot
	[m2]	[W/m²K]	°C	W	W				[W/°C]
wall without win	1120.0	1.83	18.5	37917.6	3791.8	1895.9			43605.2
roof	200.0	1.39	18.5	5143.0	514.3	257.2			5914.5
floor	234.0	1.20	18.5	5194.8	519.5	259.7			5974.0
doors	18.9	5.80	18.5	2028.0	202.8	101.4			2332.2
windows	23.1	5.80	18.5	2478.6	247.9	123.9		35571.4	2850.4
								Qtotatle	96247.7	W
								GV=Q/(V*DT)	0.80764082	[W/m3ºC]

Performance Energetica	493.5861333	(kWh/m2 vit)
Bisogno Energetico per il riscaldamento del piano	115499.1552	kWh/vit
Costi annuali per il riscaldamento per l'intero edificio	1616988.173	Leke/vit
	11549.91552	euro / year

Annual Costs for a family	20212.35216	Leke/vit
Costs for a family in a month	144.373944	euro/anno
Annual Costs for a family	7.2186972	euro mese

Energy costs of the building are calculated here as the amount of total Energy needs for heating for the floor area in kWh/year and the Annual costs for heating in Leke(Albanian coins) /year.

Energy needs for heating are Initially Energy performance * floor area and "Initially Energy performance" is the [GV=Q/(V* ΔT)]/ /(1000*floor area in m2)

Q=Total losses

V= Volume

EXISTING SITUATION

Initially Energy performance	493.59	(kWh/m2 year)
Energy needs for heating for the floor	115,499	kWh/year
Annual costs for heating	1,616,988.17	Leke/year
	11,549.92	Euro/year

INVESTMENTS

Interventions	Surface	Costs	
External layer of 6 cm of thermoinsulation	3847	5,924,380	Leke
Serramenti	42.0	529,200	Leke

total investiments		6,453,580	Leke
		46,097.00	Euro

	U [W/m²K]	Energy Performance of the building [kWh/m2 year]	Costs Before interventions [euro/year]	Costs After Interventions [euro/year]	Savings [euro/year]	Expenses Costs	Investments return [year]
Muro perimetrale di 25 cm	1.83	493.59	11549.92				
Muro perimetrale di 25 cm + termisolamento di 3 cm	0.77	288.1213867		6742.04	4807.88	11200.00	2.3
Muro perimetrale di 25 cm + termisolamento di 6 cm	0.49	233.6538453		5467.50	6082.42	16800.00	2.8
Muro perimetrale di 25 cm + termisolamento di 3 cm + mattone forato di 8 cm	0.32	201.0896213		4705.50	6844.42	24640.00	3.6
Muro perimetrale di 25 cm + termisolamento di 6 cm + mattone forato di 8 cm	0.26	167.2460885		3913.56	7636.36	33600.00	4.4

Case 2. Multifamily residential house constructed in 2013

No.	Case study	year of construction
1	Multifamily residential house	2013

Width	Length	Height	Floor Area	Volume	No. Floors	Envelope Area (5 facades)	S/V	perimeter
[m]	[m]	[m]	[m2]	[m3]		[m2]		
14.5	37	32	**683**	**21856**	**10**	**4619**	**0.03**	123

case 3

Architectonic Element	Area	U	Tin - T out	Losses because of transimittion (Qt)	Thermal bridges (Qt)	Losses because of orientation (Qt)	Losses because of Infiltration	Qtot
	[m2]	[W/m²K]	°C	W	W			[W/°C]
wall without windows	3847.0	1.72	18.5	122411.5	12241.2	6120.6		140773.3
roof	600.0	0.37	18.5	4107.0	410.7	205.4		4723.1
floor	695.0	1.20	18.5	15429.0	1542.9	771.5		17743.4
doors	52.0	2.80	18.5	2693.6	269.4	134.7		3097.6
windows	37.0	2.80	18.5	1916.6	191.7	95.8	200146.3	2204.1

Qtotatle	368687.7	W
GV=Q/(V*DT)	0.39871175	[W/m3C]

Energy performance	469.7270968	(kWh/m2 year)
Energy needs for heating for the floor	326460.3323	kWh/year
Annual costs for heating for the whole building	4570444.652	Leke/year
	32646.03323	euro/year

EXISTING SITUATION

Initially Energy performance	469.73	(kWh/m2 year)
Energy needs for heating for the floor	326,460	kWh/year
Annual costs for heating	4,570,444.65	Leke/year
	32,646.03	Euro/year

INVESTMENTS

Interventions	Surface	Costs	
External layer of 6 cm of thermoinsulation	3847	5,924,380	Leke
Serramenti	89.0	1,121,400	Leke
total investiments		7,045,780	Leke
		50,327.00	Euro

	U [W/m²K]	Energy Performance of the building [kWh/m2 year]	Costs Before interventions [euro/year]	Costs After Interventions [euro/year]	Savings [euro/year]	Expenses Costs	Investments return [year]
Muro perimetrale di 20 cm, con mattoni perforati	1.72	469.7270968	32646.03				
Muro perimetrale di 20 cm, con mattoni perforati + termisolamento di 3 cm	0.75	248.467303		17268.48	15377.56	11200.00	0.7
Muro perimetrale di 20 cm, con mattoni perforati + termisolamento di 6 cm	0.48	186.8795253		12988.13	19657.91	16800.00	0.9
Muro perimetrale di 20 cm, con mattoni perforati+ termisolamento di 3 cm + mattone forato di 8 cm	0.321	150.6111673		10467.48	22178.56	24640.00	1.1
Muro perimetrale di 20 cm, con mattoni perforati+ termisolamento di 6 cm + mattone forato di 8 cm	0.31	148.1020357		10293.09	22352.94	33600.00	1.5

Due to energy performance calculations made in two buildings, we can see that the energy performance of the buildings if we add a layer of six centimeters in both buildings, improve a lot in comparison with the existing situation. In the first case, the costs for energy heating are reduced from 12080.6 euro per year in 5557.65 euro per year and the time of return of the investment is seven years. In the second building the costs for energy heating are reduced from 34231.35 euro per year in 17585.54 euro per year and the time of return of the investment is three years. That means that the energy losses in the second case are bigger and the savings with the new interventions are bigger in the energy savings.

Conclusions

The main goal of this research is giving a contribution in the sustainable development of the residential space in Tirana and defining some possible strategies to be applicable in the existing residential buildings constructed before and after nineties. The quality of facades in the existing stock of the buildings, except the architectural perspective has an emergent need for interventions to improve the degradation over time and it is an important architectonic element, which is closely associated with the thermal losses of the building and the creation of residential warm environments, thus affecting also in the energy consumption costs. Residential blocks built before nineties, have established need for reconstruction and interventions to adapt the volume to the new energy requirements. New buildings constructed in the last three decades with facades made of bricks of twenty centimeter, shows high thermal losses and in the presence of thermal

bridges is created mold and moisture inside the living space, thereby leading to the need for interventions in the façade, roofs and openings to reduce thermal loss, creating so warm environments with less energy expenses. The big energy losses because of the bad quality of the perimeter wall, the presence of the moisture and mold inside the living space, the plastering degradation in the major stock of new and old buildings, became a focal point of the research. Possible interventions are proposed reflecting in terms of not only international references and examples how to improve the outside wall but also referring to some calculation in situ to define better the problem. There has been made some calculations of thermal transmittance of the wall, or the U-value, to see the rate of the heat transfer from the inside living space and the energy performance of the wall as it is now and how can it improve by adding other layers.

In conclusion, there have been proposed some interventions to improve the residential living space. In the building scale, there are proposed intervention in the façade by adding other layers of thermal insulations and second layers to increase the energy performance as bricks or panels of different materials, or green element that can improve building performance in terms of architectural point of view and also the energy consumption of the building as green facades, green roofs, and the elimination of thermal bridges.

Bibliography

[1] Bergman, D. (2012) *Sustainable design. A Critical Guide,* Princeton Architectural Press, New York

[2] Brookes, A. J., Grech, Ch. (1990) *The building envelope. Applications of new technology cladding,* Butterworth Architecture, London

[3] Dobjani, E., Barandovski,I., Nelkovska, O., *Quality of life changes the quality of space*, (2015) Habitat 3, Tirana

[4] Dobjani, E., (2010) *Città e Abitazione. Tirana 1920-2006,* A+P 5, Tirane

[5] Faja, E., (2010) *Gjeneza e Arkitekturës moderne dhe e realizmit socialist në Shqipëri, në vitet 1945-1980*, (available in 55 Magazine Online, http://gazeta55.al/gjeneza-e-arkitektures-moderne-dhe-e-realizmit-socialist-ne-shqiperi-ne-vitet-1945-1980/)

[6] Rogers, R., (1997) *Cities for a small planet*, ed. by Philip Gumuchdjian Faber & Faber

[7] Giancotti, A., (2012) *Trasformare l'involucro. Conservazione e riscrittura dell'imagine nel patrimonio dell'edilizia residenziale pubblica*, in Todaro, B., De Matteis, F., (a cura di) *Interventi sull'abitare. Linee guida per la riqualificazione dei quartieri innovativi nell'Italia centromeridionale*, Propsettive Edizioni, Roma

[8] Magwood, Ch., (2017) *Essential Sustainable Home Design_ A Complete Guide to Goals, Options, and the Design Process,* New Society Publishers

[9] Haddock, S. V., Moulaert, F., (2009) *Rigenerare la città. Pratiche di innovazione sociale nelle città europee,* il Mulino, Bologna

[10] Hadjri, K., UCLan, (ed.)(2004) *Readings on contemporary housing research,* in Oikonet, A global multidisciplinary network on housing research and learning

[11] L. Reale, (2015) *La Residenza collettiva,* SE Sistemi Editoriali, Napoli

[12] Magwood, Ch., (2017) *Essential Sustainable Home Design. A complete guide to goals, options, and the design process,* Canada

[13] Misja, V., Misja, A., (2004) *Veshtrim mbi situaten e banesave ne Shqiperi*, Akademia e Shkencave te Shqiperise, Instituti Ekonomise, . Tirane

[14] Riza, E., (2009) *Kapitalizmi, si i ndryshon banesat tiranase,* Gazeta Shqipetare, Tirane

[15] Sergi, G., (2008) *Tirana, una città emergente. Politiche urbane, Piani e Progetti*, COEDIT Cormagi Editore, Genova

[16] Smith M., Whitelegg, J., Williams N. J., (1998) Greening the Built Environment, earthscan, London

[17] Todaro, B., De Matteis, F., (a cura di) (2012) *Interventi sull'abitare. Linee guida per la riqualificazione dei quartieri innovativi nell'Italia centromeridionale*, Propsettive Edizioni, Roma

[18] Tsenkova, S., (2005) *Trends and Progress in Housing Reforms In South Eastern Europe*, Paris

[19] Zucchi, V., (2011) *La qualità ambientale dello spazio residenziale,* Franco Angeli

[20] Dastbaz, M., Strange, I., Selkowitz, S., (Ed.2016), *Building Sustainable Futures Design and the Built Environment*, Springer International Publishing Switzerland

[21] Mumovic, D., Santamouris, M., ed. (2019) A Handbook of Sustainable Building Design and Engineering *An Integrated Approach to Energy, Health and Operational Performance,* Routledge, New York

[22] SABNIS G. M., ed. (2016) *Green building with concrete. Sustainable design and construction,* CRC Press, Taylor & Francis Group, NW