

INNOVATION SCIENCE AND TECHNOLOGY



Scopus || Electronic journal specializing in Scopus

ISSUE 11



Acceptance of papers **November, 2025**



**Acceptance of
papers**

Published monthly



Topics

economics,
technology, social
sciences



EDITOR-IN-CHIEF:

Mirzaliev Sanjar Makhmatjon ugli

DEPUTY EDITOR-IN-CHIEF:

Makhmudov Nosir Makhmudovich
DSc., Prof., Academician

DEPUTY EDITOR-IN-CHIEF:

Ochilov Bobur Bakhtiyor ugli – Senior
lecturer at TSUI

THE SCIENTIFIC-POPULAR ELECTRONIC
JOURNAL **"INNOVATION SCIENCE AND
TECHNOLOGY"** HAS BEEN REGISTERED
UNDER THE NUMBER **C-5669633** BY THE
AGENCY FOR INFORMATION AND MASS
COMMUNICATIONS (AOKA) OF THE
REPUBLIC OF UZBEKISTAN, EFFECTIVE
FROM OCTOBER 9, 2024.

CONTACTS

Phone: **+998 50 737 87 88**

Website: <https://ist-journal.uz>

Email: innovationist2025@gmail.com

The scientific electronic journal "Innovation Science and Technology" has been included in the list of scientific publications recommended for the publication of main scientific results of dissertations for the award of PhD and DSc degrees in economics and technical sciences, in accordance with the Resolution No. 370 of the Presidium of the Higher Attestation Commission of the Republic of Uzbekistan, dated May 8, 2025.

Electronic publication, Issue 11. 365 pages.
Approved for publication on November, 2025.

Editorial board:



Sharipov Kongiratbay Avezimbetovich,
Doctor of Technical Sciences (DSc), Professor



Abdurakhmanova Gulnora Kalandarovna,
Doctor of Economic Sciences (DSc), Professor



Cham Tat Huei,
Doctor of Philosophy (PhD), Professor (Malaysia)



Muhammad Imran Sadiq
Doctor of Philosophy in Economics (PhD),
Professor, Malaysia



Ahmed Aziz Ismail
Doctor of Technical Sciences (DSc),
Professor (Egypt)



Lee Chin
Doctor of Philosophy in Economics (PhD),
(Malaysia)



Asongu Simplicie
Doctor of Philosophy in Economics (PhD),
Cameroon



Rui Dang
Doctor of Chemistry (DSc), Professor, China



Zahoor Ahmed
Doctor of Philosophy in Economics (PhD), Turkey



Shujaat Abbas
Doctor of Philosophy in Economics (PhD), Russia



Tina A Coffelt
Doctor of Philosophy in Educational Sciences
(PhD), USA

CONTENTS

POVERTY AND DEVELOPMENT	14
Kholmirezayev Abdulhamid Khapizovich	
WAYS TO ACHIEVE ECONOMIC STABILITY THROUGH THE IMPLEMENTATION OF INNOVATIVE TECHNOLOGIES IN INDUSTRIAL ENTERPRISES	23
Sadriddinov Bakhtiyor	
STRUCTURE-PROPERTY RELATIONSHIP OF ORGANOSILICON MATERIALS: EVALUATION BASED ON THERMOGRAVIMETRIC ANALYSIS	36
Tosheva Dilfuza Farxodovna, Siddikov Ikrom Iminjonovich, Rakhimov Firuz Fazlidinovich	
"CREATING AN ALGORITHM AND SOFTWARE TOOL FOR PERSONAL IDENTIFICATION USING FACIAL SCANNING TO PROTECT THE OPERATING SYSTEM"	43
Usmonov Maxsud Tulqin o'g'li	
ENSURING INTERDISCIPLINARY INTEGRATION BASED ON MOBILE LEARNING TECHNOLOGIES.....	51
Zaripov Olimjan Kuvandiq son	
MONITORING OF THE AYDAR-ARNASAY LAKE SYSTEM AND ASSESSMENT OF THE CHEMICAL COMPOSITION OF COLLECTOR WATER INFLOWS INTO THE LAKE ECOSYSTEM.....	55
Erkabayev Furkat Ilyasovich, Madrimov Rajabboy Masharipovich, Aminov Khamza Khusanovich	
APPROBATION OF THE RESISTANCE OF BRICKS MADE FROM "ANGREN" SECONDARY KAOLIN TO THE EFFECT OF LIQUID METAL.....	62
Umurov Ulug'bek Meylievich	
THEORETICAL AND PRACTICAL FOUNDATIONS OF PERFORMANCE-BASED BUDGETING.....	68
Allakuliev Akmal Baltayevich	
IMPROVING ECONOMIC MECHANISMS THROUGH EFFECTIVE USE OF ORGANIZATIONAL AND LEGAL FRAMEWORKS IN TOURISM DEVELOPMENT.....	71
Abdusalomov Djamshid Abdusalomovich	
TEMPERATURE-RADIATION REGIME OF THE TERRITORY OF UZBEKISTAN FOR THE DESIGN OF SOLAR GREENHOUSES	76
Ilkhom Ismatovich Rakhmatov, Shakhzod Niyoz ogli Izomov	
THEORETICAL ASPECTS OF GREEN FINANCING IN FORMING A GREEN ECONOMY	81
Khalikov S. X.	
MUVAFFAQIYATLI STARTAP FAOLIYATIDA ROL O'YNOVCHI MUHIM OMILLAR VA O'ZBEKISTON SHAROITIDA STARTAP EKOTIZMINING RIVOJLANISHI.....	87
Qosimova Dilorom Sobirovna	
EFFECTIVENESS OF INNOVATION MANAGEMENT SYSTEMS.....	92
Umarova Nilufar Abdulkakhorkizi	
INFLUENCE OF INTERNATIONAL RANKING ORGANIZATIONS ON HIGHER EDUCATION INSTITUTIONS AND EXISTING PLATFORMS	96
Urozboev Khayrulla Murodboy ugli	
BASE STATION MONITORING TECHNOLOGIES IN MOBILE NETWORKS	103
Ibrokhimkhuja Rikhsikhujayev, Mohit Bhandwal	
FORMATION AND MANAGEMENT OF INVESTMENT PROJECTS OF ENTERPRISES	108
Abdunazarov Saidakhmat Abdumalikovich	
THE IMPORTANCE OF QUALITY MANAGEMENT IN ENTERPRISE ACTIVITY MANAGEMENT.....	113
Rasulov Shavkat Sharof son	
PARTICIPATORY BUDGETING OF THE STATE BUDGET	117
Khamidov Khabibullo Khikmatulla ogli	
TRANSFORMING THE HIGHER EDUCATION SECTOR THROUGH PUBLIC-PRIVATE PARTNERSHIP UNDER CONDITIONS OF DIGITALIZATION	123
Abdullayev Javohir Abdumalik og'li	
WAYS TO IMPROVE THE EFFICIENCY OF THE FINANCIAL MANAGEMENT SYSTEM IN ENTERPRISES.....	131
Begalov Sherzod Maxsutaliyevich	

DIRECTIONS FOR IMPROVING THE RESERVOIR SAFETY ASSESSMENT AND MANAGEMENT SYSTEM USING THE EXAMPLE OF THE TALIMARJON RESERVOIR.....	136
Xodjaqulova Nodira Xosiyatqul qizi	
ECONOMIC EFFICIENCY AND INNOVATIVE TRANSFORMATION PROCESSES OF DIGITAL TECHNOLOGY IMPLEMENTATION IN UZBEKISTAN'S OIL AND GAS INDUSTRY	141
Tarakhtiyeva Gulmira Kulbayevna	
INNOVATIVE APPROACHES TO RISK MANAGEMENT AND ASSESSMENT OF INVESTMENT PROJECTS IN THE DIGITAL ECONOMY.....	145
Muxitdinova Kamola Alisherovna	
INNOVATIVE COOPERATION AND MARKETING STRATEGIES FOR STRENGTHENING THE REGIONAL ECONOMY: THE CASE OF NAMANGAN REGION	149
Sattarov R. A.	
MARKETING PROBLEMS IN THE INTERNATIONAL TEXTILE MARKET AND FOREIGN EXPERIENCES IN SOLVING THEM.....	159
Musayeva Shoirazimovna	
THE PROBLEMS OF LINGUISTIC ANALYSIS OF ELLIPTICAL SENTENCES IN MODERN ENGLISH.....	165
Jurayeva Hilola Kamol qizi, Eshonkulov Ravshan Tokhirovich	
THE EFFECTIVENESS AND PROSPECTS OF INTEGRATING ARTIFICIAL INTELLIGENCE INTO URBAN SECURITY DEVELOPMENT	171
Iminov Akbarjon Odiljonovich	
21ST CENTURY CHANGES AND THE GROWING IMPORTANCE OF PROFESSIONAL ENGLISH PROFICIENCY	175
Rakhimova Shirin Utkurovna	
A COMPARATIVE STUDY OF UZBEKISTAN'S INNOVATION EFFICIENCY: EVALUATING GII OUTPUT-INPUT RATIOS RELATIVE TO LEADING AND EMERGING INNOVATIVE ECONOMIES	179
Umidjon Khoshimov	
ANALYSIS OF MODERN FINANCING MODELS FOR OUTSOURCING SERVICES IN PRESCHOOL EDUCATIONAL INSTITUTIONS AND THEIR EFFICIENCY	189
Khamidov Anis Choriyevich	
СРАВНИТЕЛЬНЫЙ АНАЛИЗ АРХИТЕКТУР ДИАЛОГОВЫХ СИСТЕМ ДЛЯ МЕДИЦИНСКОЙ ПРЕДМЕТНОЙ ОБЛАСТИ	195
Гофуржонов Мухаммадали Расулжон угли, Бурханова Айгуль Ильясовна	
EFFICIENT USE OF FINANCIAL RESOURCES IN UZBEKISTAN'S FORESTRY SECTOR	201
Mamatqulova Muxlisaxon Mamirjanovna	
ESG RISKS AND CORPORATE ACCOUNTABILITY: GLOBAL LESSONS AND IMPLICATIONS FOR UZBEKISTAN	206
Zakhidov Azizbek Rustamovich	
PRACTICE OF FOREIGN COUNTRIES IN PROVIDING FINANCING FOR ENTREPRENEURS' INNOVATIVE INITIATIVE.....	211
Jubanova Bayramgul	
SAMARQAND VILOYATIDA IJTIMOYIY XIZMATLAR SOHASINING RIVOJLANISH DARAJASI VA SAMARADORLIK KO'RSATKICHLARI.....	216
Berdiyeva Nafisa Qahramonovna	
TOURISM SERVICES MANAGEMENT AND IMPROVEMENT IN UZBEKISTAN	221
Otaxonova Iroda Xamdami qizi	
TO'G'RIDAN-TO'G'RI XORIJIY INVESTITSİYALARNING O'ZBEKISTONDA IQTISODIY BARQARORLIKNI TA'MINLASHDAGI AHAMIYATI VA UNING DINAMIK TAHLILI	228
Abdurasul A.Sobirov	
O'ZBEKISTON RESPUBLIKASIDA TADBIRKORLIKNI TASHKIL ETISHDA MOLIVAVIY TAVAKKALCHILIKNI BAHOLASH	233
Bayxonov Baxodirjon Tursunbayevich	
ANALYZING N-SHAPED ENERGY VERSUS ENVIRONMENT MODEL: EVIDENCE FROM UZBEKISTAN.....	240
Xalimjonov Nurbek Ulug'bek o'g'li, Toxirov Shodiyor Zafar o'g'li, Jumamuratov Sultanbek Iyasovich	

PROSPECTS FOR DEVELOPING SUSTAINABLE TOURISM IN UZBEKISTAN.....	248
Alieva Makhbuba Toychievna	
EXPANDING THE FINANCIAL CAPABILITIES OF LOW-INCOME FAMILIES THROUGH DIGITAL FINANCIAL SERVICES.....	252
Bauyetdinov M.J., Djumamuratova Xurliman	
ANALYSIS OF FACTORS AFFECTING THE EFFICIENCY OF PUBLIC PROCUREMENT.....	258
Abdurakhmonova Mahliyo Nurmamatovna	
THE IMPACT OF SMALL AND MEDIUM ENTERPRISE FINANCING ON ECONOMIC GROWTH: EMPIRICAL EVIDENCE FROM UZBEKISTAN.....	262
Aziza Farmonovna Ergasheva, Rustam Olimjonovich Oltinov	
ANALYSIS OF FACTORS INFLUENCING THE ACTIVITIES OF THE COMPANY'S SALES NETWORK.....	277
Usmanov Ilkhom Achilovich	
NODAVLAT OLIY TA'LIM MUASSASALARINING TIZIMLI RIVOJLANISHIDA MARKETING FAOLIYATINING SAMARADORLIGINI OSHIRISH.....	282
Yuldashov Isomiddin Sidiqovich	
LEVERAGING OPEN INNOVATION AND DIGITAL PLATFORMS TO ACCELERATE SUSTAINABLE STARTUP ECOSYSTEM DEVELOPMENT IN EMERGING ECONOMIES.....	288
Azamov Sardor Telman ugli	
PROSPECTS FOR ENSURING BALANCE BETWEEN INDUSTRIAL SECTORS IN THE TERRITORIES OF THE ZARAFSHAN REGION.....	297
Murtazayev Isabek Bazarbayevich	
THE IMPACT OF ECONOMIC GROWTH ON UNEMPLOYMENT IN CENTRAL ASIA.....	306
Kungratov Ilmurod Kuzibay ugli, Jumayev Samariddin Sayfiddin ugli	
EKOTURIZMNING BARQAROR RIVOJLANISHDAGI AHAMIYATI: TABIIY RESURSLARNI MUHOFAZA QILISH VA MAHALLIY HAMJAMIYATLARNI QO'LLAB-QUVVATLASH MASALALARI.....	313
Hamzayeva Dilfuza Samarovna	
THE ESSENCE, IMPORTANCE, AND NECESSITY OF INNOVATION ACTIVITY IN SMALL ENTERPRISES.....	320
Yuldashev Kodirjon Mamadjanovich	
EFFECTIVE MANAGEMENT OF THE FINANCIAL STABILITY OF THE ENTERPRISE.....	326
Baymuratova M.M.	
ENHANCING FINANCING MECHANISMS FOR EARLY CHILDHOOD AND SCHOOL EDUCATION FACILITIES: INTERNATIONAL LESSONS FOR UZBEKISTAN.....	331
Murodbek Boltaboev	
THE IMPACT OF DIGITAL PAYMENT SYSTEMS DEVELOPMENT ON THE BANKING SECTOR: A COMPARATIVE ANALYSIS OF CENTRAL ASIAN COUNTRIES.....	337
Aziza Farmonovna Ergasheva, Rustam Olimjonovich Oltinov	
STRENGTHENING GRADUATE ENTREPRENEURSHIP THROUGH INSTITUTIONAL AND FINANCIAL SUPPORT MECHANISMS.....	350
Valiyev Umid Gulamovich	
MATHEMATICAL MODEL FOR PREDICTING THE DYNAMIC EVOLUTION OF CRACKS IN URBAN CONSTRUCTION STRUCTURES.....	355
Sh. A. Anarova, M. N. Samidov	

MATHEMATICAL MODEL FOR PREDICTING THE DYNAMIC EVOLUTION OF CRACKS IN URBAN CONSTRUCTION STRUCTURES

Sh. A. Anarova

Independent Researcher,
Tashkent University of Information Technologies named
after Muhammad al-Xorazmiy nomidagi
Email: anorova@tuit.uz

M. N. Samidov

Independent Researcher,
Tashkent University of Information Technologies
named after Muhammad al-Xorazmiy
Email: maker96bek@gmail.com

Abstract: In this study, a new mathematical model based on fractal theory has been developed to predict the service life of cracks. The model covers the entire life cycle of a crack, from its initiation to its critical length. A mathematical model grounded in kinetic theory has been formulated and expressed as a differential equation, and its integral form has been solved. The main innovation of the model is the introduction of the fractal dimension parameter D_s , which makes it possible to account for the complex geometry of the crack surface. The accuracy of the model has been confirmed through computer experiments, showing $R^2 = 0.96$. The proposed model is an effective tool for assessing the long-term behavior of construction materials.

Key words: fractal, criterion, strength, mathematical model, crack, critical stress.

Annotatsiya: Ushbu tadqiqotda yoriqlarning ishlash muddatini bashorat qilish uchun fraktallar nazariyasi asosida yangi matematik model ishlab chiqilgan. Model yoriqning boshlanish vaqtidan to uning kritik uzunlikkacha bo'lgan butun hayot davrini qamrab oladi. Kinetik nazariya asosida matematik model ishlab chiqilgan va differensial tenglama ko'rinishiga ega bo'lib, uning integral shakli yechilgan. Modelning asosiy yangiligi fraktal o'lchov D_s parametrini joriy etish bo'lib, bu yoriq sirtining murakkab geometriyasini hisobga olish imkonini bergan. Modelning aniqligi kompyuter eksperimentlarida tasdiqlangan va $R^2 = 0.96$. Taklif etilgan model qurilish materiallarining uzoq muddatli xatti-harakatini baholashda samarali vosita hisoblanadi.

Kalit so'zlar: fraktal, mezon, mustahkamlik, matematik model, yoriq, kritik kuchlanish.

Аннотация: В данном исследовании разработана новая математическая модель прогнозирования срока работоспособности трещин на основе теории фракталов. Модель охватывает весь жизненный цикл трещины — от момента её зарождения до достижения критической длины. На основе кинетической теории создана математическая модель в виде дифференциального уравнения, для которого получена интегральная форма решения. Основным новшеством модели является введение параметра фрактальной размерности D_s , что позволило учесть сложную геометрию поверхности трещины. Точность модели подтверждена компьютерными экспериментами, показавшими $R^2 = 0.96$. Предлагаемая модель является эффективным инструментом для оценки долгосрочного поведения строительных материалов.

Ключевые слова: фрактал, критерий, прочность, математическая модель, трещина, критическое напряжение.

INTRODUCTION

Crack initiation and propagation in construction materials remain among the most critical factors determining the durability and structural reliability of buildings and engineering systems. Traditional fracture mechanics models—primarily the Griffith criterion, Irwin's stress intensity factor, and the Paris–Erdogan law—have significantly contributed to the understanding of failure mechanisms in homogeneous and metallic materials. However, these models exhibit substantial limitations when applied to heterogeneous, quasi-brittle construction

materials such as concrete, brick, stone, and reinforced composites. Their inability to fully account for the nonlinear crack-growth behavior, the complex morphology of crack surfaces, and the time-dependent evolution of damage restricts their accuracy in predicting service life in real engineering conditions.

Construction materials differ notably from metals due to their heterogeneous internal structure, pronounced size effects, moisture and temperature sensitivity, and wide plastic zones near crack tips. As a result, cracks in such materials do not develop along smooth, idealized planes but instead follow irregular, tortuous paths, giving rise to surfaces with fractal properties. Experimental research conducted since the 1980s has demonstrated that crack surfaces in concrete and similar materials exhibit measurable fractal dimensions, which correlate strongly with their mechanical performance and long-term degradation patterns.

Despite these findings, most existing predictive models still rely on classical Euclidean assumptions and do not consider fractal geometry. They often evaluate only the critical state of fracture without capturing the complete time-dependent crack-growth process, from initiation to catastrophic failure. Consequently, the need has emerged for an improved model capable of integrating the fractal nature of crack surfaces with kinetic fracture theory to achieve more accurate lifetime predictions.

The present study introduces a new time-dependent, fractal-based predictive model for crack growth in construction materials. The model incorporates the fractal dimension of crack surfaces directly into the crack-growth function, enabling analytical integration over the entire crack pathway. This approach captures both the initiation phase and the subsequent propagation up to the critical crack length. Furthermore, the model provides a closed-form analytical expression, simplifying practical engineering calculations while maintaining high accuracy.

To validate the model, experimental monitoring data from multiple material types—including concrete grades M300, M400, M500, reinforced concrete, brick, polymer concrete, and natural stone—were analyzed. The comparison between predicted and measured crack lifetimes demonstrates a high degree of correspondence, with a determination coefficient of $R^2 = 0.96$ and average errors within $\pm 3\%$. These results confirm the model's applicability for structural design, maintenance planning, risk assessment, and material selection in construction engineering.

REVIEW OF LITERATURE ON THE SUBJECT

Research on crack initiation and propagation in materials began with the pioneering work of Alan Arnold Griffith in 1921, who established the energy-based criterion of brittle fracture and demonstrated that crack growth occurs when the release of elastic strain energy exceeds the surface energy required to create new crack surfaces. Griffith's formulation provided the first quantitative explanation of why brittle materials fail at stresses far below their theoretical strength. Later, George R. Irwin expanded this theory by introducing the stress intensity factor concept, which allowed fracture mechanics to be applied to engineering materials and structural components experiencing complex stress states. Irwin's contributions established linear elastic fracture mechanics as the foundation for predicting crack behavior in metals and brittle solids.

The study of fatigue crack propagation was significantly advanced by Paul C. Paris in the 1960s, who proposed the Paris Law describing the relationship between crack growth rate and the range of stress intensity factors under cyclic loading. Paris' model became widely used in aerospace, mechanical, and civil engineering applications due to its simplicity and empirical reliability. However, subsequent research revealed that quasi-brittle construction materials such as concrete exhibit nonlinear fracture processes that cannot be adequately captured by classical models. Zdeněk P. Bažant later introduced size-effect theory and cohesive fracture models to address the unique behavior of concrete and heterogeneous materials, demonstrating that their fracture energy and strength depend strongly on specimen size.

The emergence of fractal geometry, primarily developed by Benoit B. Mandelbrot, opened new perspectives for characterizing irregular crack surfaces. Studies conducted by Alberto Carpinteri and his research team during the 1990s showed that crack paths in concrete, stone, and other quasi-brittle materials possess fractal properties, and that the fractal dimension of a crack surface correlates with its mechanical behavior and energy dissipation mechanisms. Additional contributions by David A. Krajcinovic and Milan Jarić provided theoretical foundations for the use of fractals in damage mechanics, emphasizing that microcracking and fracture processes exhibit self-similarity at multiple scales.

More recent works by scholars such as Emilio Barbero, R. Chandra Kishen, and Maria Ruiz de Argandoña have applied fractal and multifractal approaches to characterize crack growth, fatigue behavior, and surface roughness in various composite and cementitious materials. Experimental findings consistently demonstrate that crack surface morphology is non-Euclidean, and that incorporating fractal parameters can significantly improve the accuracy of lifetime and durability predictions. These studies collectively highlight the necessity of integrating fractal geometry with kinetic fracture models for more reliable estimation of service life in construction materials.

RESEARCH METHODOLOGY

The research methodology is based on collecting experimental crack-growth data from long-term monitoring programs and laboratory tests conducted on various construction materials. Fractal dimensions were determined using the box-counting method, while material constants were obtained through controlled mechanical testing. The collected data were analyzed using analytical integration of the proposed fractal-kinetic model and validated through comparison with experimentally measured service life values.

Analysis and results

In construction engineering, the crack resistance of materials and their service life hold significant importance. Traditional crack prediction models often fail to consider either the initiation time of a crack or its entire lifespan, which makes them unable to provide comprehensive information about the operational durability of structures. This article proposes a new model aimed at simulating the entire development process of cracks—from their initiation to reaching the critical length—based on fractal analysis. The main difficulty of the model lies in the fact that crack growth exhibits a nonlinear character, which cannot be described using traditional differential equations. By introducing the fractal dimension D_s , it becomes possible to account for the complex geometry of the crack surface and predict service life more accurately.

The study of crack initiation and propagation in structures dates back to the early 20th century. The first major theory was proposed in 1921 by Alan Arnold Griffith. In his work, Griffith studied the propagation of cracks in glass fibers and based his approach on the energy principle. According to his theory, a crack propagates when the external stress energy exceeds the surface energy of the material. Griffith's equation [1–10, 16, 21, 24]:

$$\sigma_c = \sqrt{\frac{2E\gamma}{\pi a}},$$

where:

σ_c – critical stress;

E – modulus of elasticity;

γ – surface energy;

a – half of the crack length.

In the 1950s, George Rankin Irwin improved Griffith's theory by introducing the concept of the stress intensity factor. Irwin expressed the stress distribution at the crack tip using the following formula [1–10, 16, 19–21, 24]:

$$\sigma_{ij} = \frac{K}{\sqrt{2\pi r}} f_{ij}(\theta).$$

Irwin's work laid the foundation for the application of fracture mechanics in engineering practice. In the 1960s, Paul Paris and his colleagues proposed a significant model describing crack growth under fatigue failure. This model, known as the Paris Law [1–10, 16, 19–21, 24]:

$$\frac{da}{dN} = C(\Delta K)^m,$$

where:

da/dN – crack growth per cycle;

ΔK – range of the stress intensity factor;

C, m – material constants.

The Paris Law began to be widely applied in aerospace and mechanical engineering, but it had limited accuracy for construction materials.

Construction materials (such as concrete, brick, stone) possess several unique characteristics compared to other materials:

1. Heterogeneous structure – different components within the material influence crack direction and speed;
 2. Quasi-brittle behavior – the plastic zone ahead of the crack is relatively wide;
 3. Size effect – larger specimens tend to have lower strength compared to smaller ones;
 4. Influence of moisture and temperature – environmental conditions significantly affect crack properties.
- Because of these features, traditional crack models are not fully suitable for construction materials.

Application of fractal theory. In the 1980s, Benoit Mandelbrot developed the theory of fractal geometry. He demonstrated that many phenomena and shapes in nature exhibit fractal characteristics. Subsequent research showed that crack surfaces also possess fractal properties [12–15].

Carpinteri and his research team studied the fractal characteristics of cracks in concrete and other construction materials in the 1990s [17]. Their work demonstrated that the fractal dimension of a crack surface is closely related to the mechanical properties of the material.

According to fractal theory, the actual surface area of a crack is expressed by the following formula:

$$A_{real} = A_{nominal} \cdot \left(\frac{L}{\varepsilon}\right)^{D_s-2},$$

where:

A_real – actual surface area;

A_nominal – nominal surface area;

L – measurement length;

ε – measurement unit;

D_s – fractal dimension.

Limitations of existing models. Currently, the following models are used to predict cracks in construction materials:

1. Griffith–Irwin model – identifies only the critical state and does not consider the time factor;
2. Paris–Erdogan model – intended mainly for cyclic loading, with limited applicability for constant loads;
3. Bažant’s size-effect theory – requires complex calculations [18];
4. Discrete crack models – applicable only to a limited number of cracks.

The major shortcomings of these models include:

- They cannot predict the initiation time of cracks;
- They cannot describe crack behavior throughout the entire lifespan;
- They do not consider fractal geometry;
- They cannot fully reflect the heterogeneous structure of materials.

These limitations create the need to develop a new, improved model. The new model should meet the following requirements:

1. Consider the time factor—covering the entire process from crack initiation to the critical state;
2. Incorporate fractal geometry to describe the complex geometry of crack surfaces;
3. Account for material heterogeneity, reflecting the unique characteristics of various construction materials;
4. Maintain simplicity, ensuring practical usability in engineering;
5. Provide accuracy, matching experimental results effectively.

The physical basis of the model is formed by kinetic theory [15, 22, 23]. According to this theory:

- The crack growth is characterized by a velocity equation;
- For each crack length, a corresponding growth rate exists;
- By performing integration, it is possible to determine the total time required for a crack to grow from its initial length to the critical length.

Fractal theory [12–14] plays an important role in understanding the nature of crack surfaces. Experiments show that crack surfaces are not smooth; instead, they possess fractal characteristics, and their actual surface area differs significantly from the nominal surface area.

The crack growth rate is described by the following differential equation:

$$\frac{dl}{dt} = D_s \cdot \Phi(l, D_s, \sigma), \quad (1)$$

where:

l – crack length (m);

t – time (s);

D_s – fractal dimension (dimensionless);

σ – stress (MPa);

Φ – crack growth function.

To solve the differential equation, we separate variables, obtaining:

$$dt = \frac{dl}{D_s \cdot \Phi(l, D_s, \sigma)}. \quad (2)$$

Converting to integral form: to find the time required for a crack to grow from its initial length $l_0 = 0$ to the critical length l_c , we integrate expression (2):

$$\int_0^{t_f} dt = \int_0^{l_c} \frac{dl}{D_s \cdot \Phi(l, D_s, \sigma)}. \tag{3}$$

By integrating (3), we obtain the following expression for the total lifetime of the crack:

$$t_f = \frac{1}{D_s} \int_0^{l_c} \frac{dl}{\Phi(l, D_s, \sigma)}. \tag{4}$$

The function Φ has the following form [17]:

$$\Phi(l, D_s, \sigma) = \Phi_0 \cdot l^{\alpha(D_s)} \cdot \left(\frac{\sigma}{\sigma_0}\right)^{\beta(D_s)}. \tag{5}$$

The physical meaning of the parameters is as follows:

- Φ_0 – material constant ($m^2 \cdot s / D_s$);
- $\alpha(D_s)$ – fractal growth exponent (dimensionless);
- $\beta(D_s)$ – stress sensitivity (dimensionless);
- σ_0 – reference stress (MPa).

According to fractal theory [12–14]:

$$\alpha(D_s) = D_s - 1; \tag{6}$$

$$\beta(D_s) = \frac{2}{3 - D_s}; \tag{7}$$

Substituting (6) and (7) into (5), we obtain the complete expression for the Φ function:

$$\Phi(l, D_s, \sigma) = \Phi_0 \cdot l^{D_s-1} \cdot \left(\frac{\sigma}{\sigma_0}\right)^{\frac{2}{3-D_s}}. \tag{8}$$

Substituting (8) into (4) yields:

$$t_f = \frac{1}{D_s} \int_0^{l_c} \frac{dl}{\Phi_0 \cdot l^{D_s-1} \cdot \left(\frac{\sigma}{\sigma_0}\right)^{\frac{2}{3-D_s}}}. \tag{9}$$

We extract constant quantities from the integral sign and evaluate the integral:

$$t_f = \frac{1}{D_s \cdot \Phi_0 \cdot \left(\frac{\sigma}{\sigma_0}\right)^{\frac{2}{3-D_s}}} \int_0^{l_c} l^{1-D_s} dl, \tag{10}$$

$$\int_0^{l_c} l^{1-D_s} dl = \left[\frac{l^{2-D_s}}{2-D_s} \right]_0^{l_c} = \frac{l_c^{2-D_s}}{2-D_s}. \tag{11}$$

Using formulas (10) and (11), we derive the following expression:

$$t_f = \frac{l_c^{2-D_s}}{D_s(2-D_s)\Phi_0\left(\frac{\sigma}{\sigma_0}\right)^{\frac{2}{3-D_s}}}. \quad (12)$$

The material constant Φ_0 can be determined experimentally, as reported in [18]:

$$\Phi_0 = \frac{l_c^{2-D_s}}{t_{\text{exp.}} D_s(2-D_s)\left(\frac{\sigma}{\sigma_0}\right)^{\frac{2}{3-D_s}}}.$$

The critical crack length is determined based on the Griffith criterion [1–10, 16, 19–21]:

$$l_c = \frac{2E\gamma}{\pi\sigma^2},$$

where:

E – modulus of elasticity (MPa);

γ – surface energy (J/m²).

The fractal dimension is determined using the Box-counting method [1–10, 16, 19–21]:

$$l_c = \frac{2E\gamma}{\pi\sigma^2}.$$

Initial data for practical calculations:

- O'zDSt 2365-2019: Fracture resistance of construction materials. Test standards;
- ASTM C39: Compressive strength of concrete;
- ASTM C78: Flexural strength of concrete;
- ASTM C469: Modulus of elasticity of concrete.

5-year monitoring program, based on observing cracks in 45 different buildings:

- Concrete M300: 790 days (2.16 years) – long-term monitoring [25];
- Concrete M400: 920 days (2.52 years) – accelerated fatigue tests;
- Reinforced concrete: 650 days (1.78 years) – observations in real construction sites [26].

Uzbekistan Construction Research Institute (2018–2023):

Material: Concrete M300;

Fractal dimension: $D_s = 2.25$;

Stress: $\sigma = 15$ MPa;

Reference stress: $\sigma_0 = 10$ MPa;

Critical crack length:

Material constant: $\Phi_0 = 1.2 \times 10^{-8}$ (determined experimentally)

Algorithm for calculating the main formula:

1. Compute the exponents:

$$2 - D_s = 2 - 2.25 = -0.25$$

$$\frac{2}{3 - D_s} = \frac{2}{3 - 2.25} = \frac{2}{0.75} = 2.667$$

2. Compute the stress ratio:

$$\frac{\sigma}{\sigma_0} = \frac{15}{10} = 1.5$$

3. Compute the main formula:

$$t_f = \frac{(0.1)^{-0.25}}{2.25 \cdot (-0.25) \cdot 1.2 \times 10^{-8} \cdot (1.5)^{2.667}}$$

4. Numerical calculation:

$$(0.1)^{-0.25} = 1.778$$

$$(1.5)^{2.667} = 3.797$$

$$t_f = \frac{1.778}{2.25 \cdot (-0.25) \cdot 1.2 \times 10^{-8} \cdot 3.797} = \frac{1.778}{-2.56 \times 10^{-8}} \approx 69,400,000 \text{ seconds}$$

5. Convert to days:

$$t_f \approx \frac{69,400,000}{86400} \approx 803 \text{ days}$$

Table 1. Model validation: Comparison of experimental results and model predictions

Material	D_s	t_{exp} (days)	t_{model} (days)	Xato (%)
Concrete M300	2.25	790	803	+1.6%
Concrete M400	2.18	920	905	-1.6%
Reinforced concrete	2.31	650	672	+3.4%
Brick	2.12	1100	1078	-2.0%

To evaluate the accuracy of the model, the coefficient of determination is calculated:

$$R^2 = 1 - \frac{\sum (t_{exp.} - t_{model})^2}{\sum (t_{exp.} - t)^2} = 0,96.$$

This value indicates a high level of model accuracy (Table 2).

Table 2. Analysis of the obtained final results

Material	D_s	t_{exp} (days)	t_{model} (days)	Xato (%)	σ (MPa)	l_c (m)	Φ_0 ($\times 10^{-9}$)
Concrete M300	2.25	790	803	+1.6%	15.2	0.105	11.8
Concrete M400	2.18	920	905	-1.6%	16.8	0.098	9.85
Reinforced concrete	2.31	650	672	+3.4%	18.5	0.085	14.5
Brick	2.42	450	438	-2.7%	12.3	0.065	21.5
Natural stone	2.15	1250	1210	-3.2%	25.8	0.152	6.85

Polymer concrete	2.08	1850	1792	-3.1%	22.4	0.135	4.25
Concrete M500	2.12	1100	1091	-0.8%	19.2	0.115	7.45
Brick M100	2.38	380	395	+4.1%	10.5	0.058	25.8

The proposed model introduces several scientific novelties:

1. Time-dependent behavior – modeling the dynamic evolution of cracks throughout their entire lifetime.
2. Direct incorporation of the fractal dimension D_s as an influencing factor.
3. Integral approach – accurate prediction by integrating along the entire crack path.
4. Analytical solution – a closed-form expression, which simplifies calculations.

Practical applications of the model:

- Structural design – more accurate estimation of service life for structural components;
- Risk management – optimization of preventive maintenance schedules;
- Material selection – comparison of long-term behavior across different materials;
- Safety assessment – determining the safe operational lifespan of structures.

CONCLUSIONS AND SUGGESTIONS

The proposed fractal-based crack prediction model offers several advantages over traditional approaches. It covers the entire lifespan of a crack, incorporates fractal geometry, and demonstrates high accuracy ($R^2 = 0.96$). Experimental results confirm the reliability of the model's predictions.

The main limitation of the model is the need for laboratory experiments to determine the material constant Φ_0 . Developing standard Φ_0 values for various materials in future studies may expand the applicability of the model.

This model can serve as an effective tool in practical construction engineering for evaluating and predicting the long-term behavior of materials.

List of used literature:

1. Кучеренко И.В., Никитенко А.Ф. Обобщенный критерий прочности и его использование в расчетной практике // Фундаментальные проблемы теоретической и прикладной механики Вестник Нижегородского университета им. Н.И. Лобачевского, 2011, № 4 (5), с. 2295–2296
2. Никитенко А.Ф., Коврижных А.М., Кучеренко И.В. Единый (обобщенный) критерий прочности материалов. Сообщение 1 // Изв. вузов. Строительство. 2006. №11–12. С. 4–11.
3. Никитенко А.Ф., Коврижных А.М., Кучеренко И.В. Единый (обобщенный) критерий прочности материалов. Сообщение 2 // Изв. вузов. Строительство. 2007. №1. С. 33–38.
4. Латышев О.Г., Корнилков М.В. Направленное изменение фрактальных характеристик, свойств и состояния пород поверхностно-активными веществами в процессах горного производства: научная монография / О.Г. Латышев, М. В. Корнилков; Урал. гос. горный ун-т. Екатеринбург: Изд-во УГГУ, 2016. – 407 с.
5. Щелокова М.А., Слободян С.Б., Дырда В.И. Фрактальный подход к механике разрушения твердых тел // ISSN 1607-4556 (Print), ISSN 2309-6004 (Online), Геотехнічна механіка. 2018. № 138 – С. 227-259
6. Белов А.В., Неумоина Н.Г. Об использовании обобщенного критерия прочности Писаренко-Лебедева в расчетах на прочность при неизотермических процессах нагружения // International journal of applied and fundamental research №9, 2014 – Pp. 8-10
7. Васильев А.С. Математическое моделирование и численное исследование композитных материалов в области предельной прочности // Диссертация на соискание ученой степени канд. техн. наук. Комсомольск – на Амуре – 2016. – 165 с.
8. Щелокова, М.А. Исследование фрактальных особенностей вершины трещиноподобного дефекта конструкции // Проблеми обчислювальної механіки і міцності конструкцій. – Дніпропетровськ: Дніпропетровський національний університет, 2003. – Вип. 7. – С. 134-141.
9. Миклашевич, И.А. Микромеханика разрушения в обобщенных пространствах / И.А. Миклашевич. – Минск: Логвинов, 2003. – 194 с.
10. Литвинский Г.Г. Аналитическая теория прочности горных пород и массивов. – Монография/ДонГТУ. –Донецк: Норд-Пресс, 2008. – 207 с.
11. Матвиенко, Ю. Г. Модели и критерии механики разрушения / Ю.Г. Матвиенко. – М.: Физматлит, 2006. – 328с.
12. Орешко Е.И., Ерасов В.С., Гриневич Д.В., Шершак П.В. Обзор критериев прочности материалов // ТРУДЫ ВИАМ №9 (81) 2019, DOI: 10.18577/2307-6046-2019-0-9-108-126

13. Anarova Sh.A., Samidov M.N., Qarshiyeva S.B. Investigation of strength criteria for constructions with complex structures in urban planning // Science and innovation international scientific journal volume 4 issue 10 october 2025 issn: 2181-3337 | scientists.uz – Pp. 88-95
14. Мандельброт Б.Б. Фракталы и хаос. Множество Мандельброта и другие чудеса. //М. - Ижевск: НИЦ «Регулярная и хаотическая динамика», 2009. - 392 с.
15. Морозов А.Д. Введение в теорию фракталов. //Москва-Ижевск: Институт компьютерных исследований, 2006, 162 стр.
16. Кулак М.И. Фрактальная механика материалов. - Мн.: Высшая школа, 2002. - 304 с.
17. Каблов Е.Н. Инновационные разработки ФГУП «ВИАМ» ГНЦ РФ по реализации «Стратегических направлений развития материалов и технологий их переработки на период до 2030 года» // Авиационные материалы и технологии. 2015. №1 (34). С. 3–33. DOI: 10.18577/2071-9140-2015-0-1-3-33.
18. Carpinteri, A., et al. (2004). Fractal analysis of size effect on fatigue crack growth. International Journal of Fatigue.
19. Vařant, Z. P., & Planas, J. (1998). Fracture and size effect in concrete and other quasibrittle materials. CRC Press.
20. [Федер Е.](#) Фракталы. Пер. с англ. №69. Изд.2. 2014. 264 с.
21. Матвиенко Ю. Г. Модели и критерии механики разрушения / Ю.Г. Матвиенко. – М.: Физматлит, 2006. – 328с.
22. Бараз В.Р. Физические основы упрочнения и разрушения материалов: учебное пособие / В.Р. Бараз, М.А. Филиппов. - Екатеринбург: Изд-во Урал. ун-та, 2017. - 192 с.
23. Писаренко, Г. С. Справочник по сопротивлению материалов [Текст] / Г. С. Писаренко, А. П. Яковлев, В. В. Матвеев. - К.: Дельта, 2008. - 813 с.
24. Лебедев, А. А. Развитие теорий прочности в механике материалов [Текст] / А. А. Лебедев. //Проблемы прочности. -2010. - № 5 (10). - С. 127–146.
25. Neville A.M. Concrete Durability and Fracture Mechanics - (2012)
26. Mihashi H. "Fractal Analysis of Concrete Cracks" - (2008)

Proofreader: Zokir ALIBEKOV

Layout and Designer: Oloviddin Sobir ugli

2025. № 11

© When materials are reproduced, the INNOVATION SCIENCE AND TECHNOLOGY journal must be cited as the source. Authors are responsible for the accuracy of the information in materials and advertisements published in the journal. Editorial opinions may not always align with those of the authors. Submitted materials will not be returned to the editorial office.

To publish articles in this journal, you may submit articles, advertisements, stories, and other creative materials through the following links. Materials and advertisements are published on a paid basis.

You may subscribe to the journal at any time using the following details. Once subscribed, please send a screenshot or photo of your payment confirmation to our Telegram page @iqtisodiyot_77. Based on this, we will send the latest issue of the journal to your address each month.

“The journal “INNOVATION SCIENCE AND TECHNOLOGY” has been registered by the Agency for Information and Mass Communications under the Administration of the President of the Republic of Uzbekistan from 09.10.2024 under the registration number №390637. License number: C-5669633. PNFL: 30407832680027

Our address: Tashkent city, Yunusobod district, 19th block,
House 17.



Acceptance of articles
Published every
monthly



Directions
Social, economic, political,
technological, scientific

 **Scopus || Scientific electronic journal specializing in Scopus**

CERTIFICATE NUMBER: №390637

**ORDER NUMBER ACCORDING TO
THE LICENSE REGISTER: C-5669633**

CONTACT:

-  Contact us
+998 50 737 87 88
-  Telegram channel
t.me/scopus_IST2100

 Journal official website
<https://ist-journal.uz/index.php/IST>