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Application of Optimization in Reinforced Concrete Structural Design-A Review

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***Abstract*—The improvements in the reinforced concrete plan and late patterns for conservative structural frameworks have turned the planners to utilize present day heuristic techniques despite precise strategies. As of late, heuristic, and meta-heuristic approaches that apply blends of various heuristics with or without conventional search are proposed to get ideal designs. It is well known that material cost is a significant issue in planning and developing reinforced concrete structures, hence builds are confronted with the test of planning productive and cost-compelling structural frameworks. This study means to give fundamental information about the most generally utilized present-day (meta) heuristic optimization techniques, and their application in the plan of reinforced concrete structures.**

***Index Terms*— application; design; heuristic; reinforced concrete; structures; review.**

I. INTRODUCTION

Reinforced concrete development is exceptionally mainstream worldwide as it comes from the wide accessibility of reinforcing steel just as the concrete fixings. In any case, in contrast with steel structures, the enhancement of reinforced concrete structures is increasingly confused; this is incompletely in light of the fact that RC structures can be surrounded with a semi-unbounded arrangement of part measures and different examples of reinforcement [1]. Likewise, in the advancement of steel structures, only one material is thought of and the expense is straightforwardly relative to the heaviness of the structure, while on account of RC structures, we have multi-material, three diverse cost things comprising of concrete, steel and formwork, and every one of these boundaries impact the complete expense of the structure. Consequently, the streamlining issue changes into the choice of a fitting blend of areas measurements and the amount of reinforcement with the end goal that the general expense of the structure is insignificant [2]. There are fundamentally two ideal design approaches careful and heuristic, however when the quantity of design factors is huge, the streamlining issue gets intricate for which the specific methodology is regularly incapable to discover the arrangement inside a sensible measure of time then heuristic strategies dependent on transformative calculation and computerized reasoning methodology are utilized. This paper presents a review of the most mainstream (Meta) heuristic methods utilized for tackling run of the mill streamlining issues in the field of reinforced auxiliary design. Certain highlights of both old style and heuristic procedures are talked about in area II. At that point, Section III portrays utilizations of (Meta) heuristic methods for RC auxiliary design and for each such issue a short depiction is introduced.

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II. Optimization Procedures

A. Customary optimization techniques

The customary techniques for optimization are helpful in finding the ideal solution of constant and differentiable capacities. These strategies are explanatory and utilize the methods of differential calculus in finding the ideal focuses [3]. Since a portion of the down to earth issues include target works that are not nonstop and differentiable, along these lines traditional optimization strategies have restricted degrees in reasonable applications. These methods utilize differential calculus in finding the ideal solution and lead to a lot of nonlinear synchronous conditions that might be hard to settle [4]. The normal troubles with a large portion of the traditional optimization procedures are intermingling to an optimal solution relies upon the picked beginning solution and will in general stall out to a suboptimal solution [3,4]. Moreover, a calculation productive in taking care of one inquiry and optimization issue perhaps not effective in tackling an alternate issue and in taking care of issues having discrete factors.

B. Heuristic procedures

Heuristic optimization procedures are the stochastic inquiry methods that utilization data from the hunt so far to control the probabilistic decision of the following focuses to attempt. They can take care of extremely complex issues that cannot be explained by enumerative and analytics-based strategies. Heuristic techniques commonly require far less time than careful strategies. Heuristics can be useful (form an answer piece by piece) or improvement based. The basic component in these algorithms is that they join rules and arbitrariness to emulate natural wonders to settle troublesome and confused certifiable optimization issues. The alluring highlights of heuristic optimization methods are the capacity of advancing frameworks that have consistent, discrete, or whole number plan factors. The issues are unraveled iteratively, and their answer isn't generally the worldwide ideal, this relies upon the multifaceted nature of the issue. The odds to get caught in nearby desired states are less. Meta-heuristic In a general system optimization heuristics is likewise called meta-heuristics [5] which can be considered as a general skeleton of a calculation pertinent to a wide scope of issues. A meta-heuristic may advance to a specific heuristic when it is specific to take care of a specific issue. Meta-heuristics are comprised of various segments and if parts from various meta-heuristics are amassed, we get a half and half meta-heuristic. This permits us to envision an enormous number of new procedures. The development of crossover meta-heuristics is inspired by the need to accomplish a decent tradeoff between the abilities of a heuristic to investigate the hunt space and the likelihood to abuse the experience collected during the inquiry [6].

A considerable lot of meta-heuristic algorithms are proposed by the simulation of natural procedures. The most notable and oftentimes utilized evolutionary optimization method, genetic algorithms (GAs), was propelled by Darwin's natural selection hypothesis, which depends on the possibility of natural selection. This technique was created considering the standards of genetics and advancement and copies the proliferation conduct saw in biological populaces [7]. Particle swarm optimization (PSO) is another stochastic optimization strategy spurred by the social conduct of winged creature flocking and fish schooling [8]. PSO has a populace of people that travel through pursuit space and every individual has a speed that goes about as an administrator to acquire another arrangement of people. People, called particles, alter their developments relying upon both their own understanding and the populace's understanding. Ant colony optimization (ACO) is a helpful inquiry strategy that mirrors the scavenging conduct of genuine ant states [9]. The ant algorithms impersonate the methods utilized by genuine ants to quickly set up the briefest course from a food source to their home and the other way around by utilizing pheromone trails which assume the job of roundabout interchanges between the ants. Congruity search (HS), another optimization calculation, mimics the melodic exhibition process which happens when an artist scans for a superior condition of agreement [10]. Jazz extemporization looks to discover musically satisfying amicability like the ideal plan process which tries to locate the ideal arrangement. The pitch of every instrument decides the stylish quality, similarly as the target work esteem is controlled by the arrangement of qualities relegated to every choice variable. Man-made reasoning is an incredible information-based methodology that can manage the high nonlinearity of down to earth frameworks. Among their valuable highlights are the capacity to learn and fabricate the experience inside a period and the capacity to store the information they learn enlivened by human insight. Fake neural systems and fluffy rationale are the most important computerized reasoning methodologies that have been applied to structures. Within the main investigations of heuristic methods applied to structures is the optimization of the heaviness of steel structures [11-12]. As respects, RC structures, the pioneering use of heuristic calculation incorporates crafted by Coello et al. [13] who applied the genetic calculation to the financial optimization of RC bars. As of late, there have been various utilizations of heuristic methods to RC structures. Additionally, the development of PC execution empowers the scientists to actualize these heuristic algorithms which include a ton of calculation work and produce a structure that is really advanced in concurrence with the architect's understanding, limitations, and norms given by code of training. Numerous optimization issues in RC Structures incorporate an ideal plan for the accompanying.

- Execution of Structural framework
- Sectional measurements
- Flexural quality
- Installed CO_2 outflow
- Fortification measuring and dividing
- Control of deflection

The ideal RC auxiliary plan is surveyed from the previously mentioned at least one basic highlights. In this segment, a short overview of the most agent uses of the (Meta)-heuristic strategies in the field of basic optimization is introduced. The review is neither far-reaching nor complete yet is meant to give a plan to the methods being utilized nowadays.

C. Genetic algorithm based evolutionary optimization procedures

Genetic Algorithm (GA) is the most notable agents of developmental algorithms. In GA, a population with a fixed number of people is made. Subsequent to assessing the wellness scores of people, profoundly fit individuals are permitted to endure and helpless people with low wellness scores are disposed of. Great people experience some genetic administrators, for example, choice, crossover, and transformation to create the people to come. The previously mentioned process is rehashed similarly for a fixed number of ages or until a predefined assembly model is accomplished. A portion of the pioneer uses of GA in RC structural plan have been checked on in [14-26]. It was appeared in [27-28] that the Genetic algorithm streamlining agent did a surprising exertion on limiting the costly material and the exhibition of the genetic algorithm utilizing various strategies for crossover and determination could differ starting with one issue then onto the next. From the accessible writing, it has been seen that the GA is the most generally utilized developmental algorithm alone or by consolidating with other accurate and heuristic techniques as a half and half algorithm in this field.

D. Simulated annealing based optimization procedures

A ground-breaking optimization procedure, which was developed in the second half of the twentieth century, is simulated annealing. In this strategy, wellness scores in GAs are supplanted by vitality levels. A vitality level is characterized by the end goal that it speaks to how great the arrangement is. The objective is to locate the best arrangement by limiting vitality. This technique utilizes the annealing procedure of a thermo dynamical framework. In the annealing procedure, the temperature of a thermo dynamical framework at first at a high vitality level is dropped to a level at which the framework arrives at its base vitality. In this method, in contrast to genetic algorithms, just two states (current and competitor state) are assessed rather than a fixed number population. In the event that the applicant state gives a lower vitality level, at that point it is acknowledged as the present status. Be that as it may, if the applicant state gives a higher vitality level, it isn't discarded without a moment's delay. A test called the Metropolis test is performed whether the competitor state is acknowledged or not. This test relies upon the temperature and distinction between the vitality levels of the two states. The methodology plot above is rehashed a specific number of times at this temperature. At that point, the temperature is chilled off and the entire system is rehashed. At the point when the temperature is dropped to an incentive around zero, it is trusted that the framework has its base vitality level. The conventional way to deal with configuration did not completely enhance the utilization of materials. Nonetheless, structural optimization techniques are a reasonable option in contrast to plans dependent on experience is appeared from [27-30].

E. Ant colony optimization for RC designs

This heuristic method was first presented by Colorni et al. [25-27] mirrors the way ants scan for food and discover their way back to their home. Initial, an ant investigates its neighbourhood haphazardly. When a wellspring of food is discovered it begins to ship food to the home leaving hints of pheromone on the ground which will manage different ants to the source. The force of the pheromone follows relies upon the quantity and nature of the food accessible at the source just as from the separation among source and home, with respect to a short separation more ants will go on a similar path in a given time span. As the ants ideally travel along an important path their conduct can advance their work. Pheromone trails vanish and once a wellspring of food is depleted the path will vanish and the ants will begin to look for different sources. Ant colony optimization (ACO) is the use of ant conduct to the computational calculations and can take care of discrete ideal basic issues. It likewise has extra fake qualities, for example, memory, perseverance, and discrete time. The utilization of ACO in the ideal plan of fortified solid structures is found in the writing [31-33].

F. Harmony search optimization methods for RC designs

The as of late created Harmony search (HS) meta-heuristic algorithm [33] is based on common melodic execution forms that happen when artists search for a superior condition of harmony, for example, during jazz extemporization [34]. When contrasted with customary numerical improvement algorithms, the HS algorithm forces less scientific prerequisites to tackle streamlining issues, and the likelihood of turning out to be captured in a local optimum is decreased in this algorithm. Since the HS algorithm utilizes a stochastic irregular search, it has another worldview subsidiary [35]. The algorithm considers a few arrangements vectors all the while, in a way like the GA. The writers [36-38] proposed harmony search-based algorithms for the optimum cost structure of fortified solid cantilever holding dividers and joined the harmony search and molecule swarm improvement with the uninvolved assemblage and ACO for getting the arrangement of the optimum plan of strengthened solid casings. They contemplated the optimum point by point structure of fortified cement consistent shafts utilizing the harmony search algorithm. Additionally, an optimum structure of solid cantilever holding dividers utilizing the harmony search algorithm has been acted around the same time.

G. Particle swarm based optimization procedures

Particle swarm optimization (PSO) is a search calculation that depends on a populace of arbitrary arrangements, alluded to as particles. Every particle speaks to a possible arrangement. The particles have a velocity, which moves them all through the search space. These speeds are powerfully balanced by the verifiable conduct of the particles. This alteration of velocity forces the particles to move a typical way. The PSO calculation was first intended to re-enact winged creatures looking for food [43]. PSO was first presented in 1995, and from that point forward, numerous progressions have been made to improve the combination of the PSO and expanding the assorted variety of the multitude. Particle swarm advancement procedure has been applied to an assortment of RC structure plan issues [44-52].

H. Artificial bee colony (ABC) optimization techniques

As of late, Karaboga built up another optimization algorithm called the Artificial Bee Colony (ABC) algorithm [39]. The ABC algorithm was initially presented for numerical optimization issues dependent on the foraging conduct of a bumblebee swarm. Further upgrades of the ABC algorithm have been completed by Karaboga and Basturk [40]. In this model, the foraging bees are ordered into three unique sorts: utilized bees, spectators, and scouts. A bee that has discovered a food source to misuse is called a utilized bee. Spectators are those holding up in the hive to get the data about the food sources from the utilized bees and scouts are the bees that are haphazardly scanning for new food sources around the hive. A restricted utilization of ABC on the RC structure was found.[41] performed affectability investigation and plan of reinforced concrete cantilever holding dividers utilizing the Bacterial Foraging optimization algorithm. [42] developed an optimization model that is fit for getting the ideal plan for reinforced concrete frames regarding cross-segment measurements and fortification subtleties. The optimization is done utilizing Artificial Bee Colony (ABC) Algorithm while fulfilling the quality and usefulness requirements.

I. Newton's gravitational based search algorithm for RC structure design

The gravitational search algorithm (GSA) is built dependent on the law of gravity and the thought of mass communications. The GS algorithm utilizes the hypothesis of Newtonian material science and its searcher operators are the assortments of masses. In GSA, there is a disconnected arrangement of masses. Utilizing the gravitational force, each mass in the framework can see the circumstance of different masses. The gravitational force is in this manner a method of moving data between various masses. The specialists are considered as items and their presentation is estimated by their masses. Every one of these articles pull in one another by a gravity force, and this force causes a development of all items all around towards the articles with heavier masses. The overwhelming masses compare to great answers for the issue. The situation of the operator compares to an answer for the issue, and its mass is resolved utilizing a fitness function. By pass of time, masses are pulled in by the heaviest mass. This mass would introduce an ideal arrangement in the search space. The creators [53] applied a recently evolved gravitational search algorithm for the improvement of holding structures. In another examination [54], a viable technique for nonlinear compelled advancement of shallow establishment is introduced. The algorithm is delegated an irregular search algorithm and didn't require starting qualities and utilized an arbitrary search rather than an inclination search, so subordinate data is superfluous. The enhancement methodology controlled all geotechnical and basic structure imperatives while lessening the general expense of the establishment. The accessible writing for the utilization of GSA is extremely less on the grounds that it is a recently presented algorithm.

J. Fuzzy based optimization techniques commonly employed in RC structure design

The possibility of fuzzy sets was first presented by Zadeh in 1965 as speculation of the traditional set hypothesis. Fuzzy sets use participation capacities to map components of the universe of talk to the unit stretch [60, 61]. The participation work consistently mirrors the highlights and confinements of the considered system with the goal that the fuzzy set precisely speaks to the issue and makes it straightforward by non-specialists. Fuzzy sets have been applied to different auxiliary system vulnerabilities by fuzzification of equivocal variables and utilizing enrolment works that speak to system attributes. A thorough useful manual for the basics and application can be found in distributed works. A study on the utilization of the fuzzy logic in the basic structure was introduced in [61, 62]. In the region of RC auxiliary plan issues, the quantity of distributed papers is generally little contrasted with the other streamlining strategies. Among those couple of papers was the one introduced in [61] in which an investigation of the ideal plan of RC structures with discrete plan variables by Fuzzy inference was talked about. A reinforced solid structure is chosen as the basic model so as to inspect the support, relevance, and combination of this calculation. The plan variables embraced in the numerical model comprises of sectional sizes and zones of the shaft. The enhancement of a reinforced solid structure that uses the aftereffects of the examination can be useful in the practical plan of the RC structure [62]. Another methodology that incorporated a hereditary calculation and a fuzzy system-based technique to the ideal plan of reinforced solid extensions, the proposed strategy is likewise appropriate for different sorts of structures. Plan variables incorporate either the shape or measurements of the solid cross-segments or the sum and area of the reinforcement. Be that as it may, extra fuzzy variables are considered to take the vulnerabilities engaged with the essential properties of the materials into account.

III. Discussions And Conclusions

Table I shows a summary of different optimization techniques commonly used for reinforced concrete structure design and their evolution through the years. The design code that will be considered in the displaying of the ideal design issue additionally influences the intricacy of the optimization issue got. Defining the ideal design of steel outlines without referring to any design code draws out a generally basic optimization issue if straight flexible auxiliary conduct is expected. Besides, if persistent design factors supposition that is likewise made, at that point numerical programming or optimality standards calculations productively finds the ideal arrangement of the optimization the issue in the two different ways of demonstrating. Optimality models calculations additionally give ideal arrangements with no trouble regardless of whether nonlinear versatile conduct is thought of in the ideal design of strengthened cement structures. Among the numerical programming procedures, it appears to be that successive numerical programming technique is the most remarkable, and it is accounted for in a few studies that it can accomplish the ideal arrangement with no trouble in enormous size steel outline design optimization. In spite of the fact that it is an inadequate assortment of work done in the region of ideal design of reinforced solid structures from the above survey work, it is presumed that impressive endeavours have been made to accomplish ideal RC structural design utilizing heuristic techniques. The evolutionary algorithm like GA and stochastic search methods like PSO has been broadly utilized in the field of RC structural design enhancement alone however different procedures like simulated annealing, harmony search, ACO, and ABC have been applied by hybridizing at least two meta-heuristic algorithms in many design issues. Different algorithms dependent on man-made reasoning like ANN, Fuzzy rationale and a recently evolved Gravitational algorithm have constrained application in this field. Although the altered renditions of the standard algorithms have additionally been utilized and demonstrated a lot of viable and powerful these are least attempted by the researchers. These strategies can be stretched out to the utilization of much progressively complex improvement issues in different spaces. The reasonable blend of various Meta (heuristic) with one another and with other precise strategies purported hybrid techniques likewise needs more consideration.

Rise of the stochastic search strategies gives basic architects with new capacities. These new methods need not bother with the inclination computations of goal capacity and requirements. They do not utilize numerical induction to figure out how to arrive at the ideal. Rather they depend on heuristics. These new optimization strategies use nature as a wellspring of motivation to create mathematical optimization techniques that are equipped for tackling complex building design issues. They are especially productive in acquiring the ideal arrangement where the design factors are to be chosen from a classified rundown. As summed up in this paper there are a few stochastic search methods that are effectively utilized in the ideal design steel outlines where the steel areas for the edge individuals are to be chosen from the accessible steel areas list, while the cut-off state design code particulars, for example, workableness what's more, quality are to be fulfilled. These methods do give ideal arrangement that can be straightforwardly utilized by the practicing designers in their ventures. In any case, they likewise have a few disadvantages. The first is that since they do not utilize numerical inferences; it is unimaginable to expect to demonstrate whether the ideal arrangement they achieve is the worldwide ideal or on the other hand it is close to ideal. The second is that they work with arbitrary numbers, and they have various boundaries which should be given qualities by the clients before their application. Determination of these qualities influences the presentation of algorithms. This requires an affectability works with various estimations of these boundaries to locate the proper values for the issue viable. Albeit a few methods are accessible, for example, adaptive genetic algorithm also, adaptive harmony search strategy where the estimations of these boundaries are balanced naturally by the algorithm itself, this is not the situation for different methods. The third downside is that they need countless basic investigation which turns out to be computationally over the top expensive for large size structures. Among the current methods some of them exceed expectations and beat others. Further research is needed to decrease the absolute number of basic examinations required by stochastic search algorithm which is computationally costly to a sensible sum. Be that as it may, the search for discovering better stochastic search methods is proceeding. It is troublesome right now to finish up which one of these methods will turn into the standard one that will be utilized in the design apparatuses of the limited component bundles that are utilized in regular practice. Be that as it may, it is not troublesome to reason that meta-heuristic methods will be standard design optimization apparatuses sooner rather than later.

TABLE I. A LITERATURE SUMMARY FOR DIFFERENT OPTIMIZATION TECHNIQUES USED IN REINFORCED CONCRETE STRUCTURE DESIGN (DEDE ET AL. 2018)

Name	**Authors of original paper**	**Year**	**References**
Simulated Annealing	Kirkpatrick S, Gelatt CD, Vecchi MP	1983	[53]
Genetic Algorithm	JH Holland	1975	[58]
Tabu Search	Fred Glover	1989	[69]
Ant Colony Optimization	Marco Dorigo	1992	[55]
Cultural Algorithm	Robert G Reynolds	1994	[59]
Particle Swarm Optimization	J Kennedy, R Eberhart	1995	[56]
Differential Evolution	Rainer Storn, Kenneth Price	1997	[52]
Harmony Search	Zong Woo Geem, Joong Hoon Kim, GV Loganathan	2001	[37]
Big Bang-big crunch optimization	K Erol Osman, Ibrahim Eksin	2006	[48]
Artificial Bee Colony	Dervis Karaboga, Bahriye Basturk	2007	[38]
Cuckoo Search Algorithm	Xin-She Yang, Suash Deb	2009	[25]
League Championship Algorithm	Ali Husseinzadeh Kashan	2009	[31]
Glowworm Swarm Optimization	KN Krishnanand, D Ghose	2009	[59]
Charged System Search	A Kaveh, S Talatahari	2010	[47]
Firefly Algorithm	Xin-She Yang	2010	[54]
Teaching-learning –based optimization	R Venkata Rao, Vimal J Savsani, DP Vakharia	2011	[50]
Backtracking Search Algorithm	Pinar Civicioglu	2013	[48]
Jaya	R Venkata Rao	2016	[58]

REFERENCES

[1] Y.Ahmet "Reinforced Concrete Frame Construction"Middle East Technical University, Turkey.

[2] Kaveh A, Sabzi O, (2011) "A comparative study of two meta-heuristic algorithms for optimum design of reinforced concrete frames", International Journal of Civil Engineering, Vol. 9, No.3.pp.193-206.

[3] Kumar N. D. (2005). Classical and Advanced Techniques for Optimization.

[4] Stutzle T. (2010). Heuristic Optimization Lecture Notes. University of Bruxelles.

[5] Birattari,M., L.Paquete, T. St¨utzle and K. Varrentrap (2001), "Classification of metaheuristics and design of experiments for the analysis of components". Technical Report AIDA-2001-05. Intellektik, Technische Universit¨at Darmstadt, Germany.

[6] Bock, F (1958). An algorithm for solving "traveling salesman" and related network optimization problems.14th ORSA meeting,St. Louis.

[7] Holland, J. (1975), "Adaptation in natural and artificial systems". Ann Arbor, MI: The University of Michigan Press.

[8] Eberhart R.C., Kennedy J. (1995), "A new optimizer using particle swarm theory". Proceedings of the 6th international symposium on micro machine and human science, Nagoya, Japan.

[9] Dorigo M. Optimization, learning and natural algorithms. PhD thesis, Dipartimento di Elettronica, Politecnico di Milano, IT; 1992 [in Italian].

[10] Geem ZW, Kim JH, Loganathan GV.(2001) A new heuristic optimization algorithm: harmony search. Simulation ;76:60–8.

[11] Alqudra M., Arafa M. and Ismail M., (2011), "Optimum Cost of Prestressed and Reinforced Concrete Beams using Genetic Algorithms", Journal of Artificial Intelligence, 4(1), pp.76-88.

[12] Kong.J., Kwok.T.C., (2006) "Preliminary design of concrete structures using genetic algorithms and spread sheets" 31st conference on our world in concrete and structures, 16-17, Singapore.

[13] Chau.K.W. and Albermani.F,(2008), "Genetic Algorithms for Design of Liquid Retaining Structure" International Conference on Engineering Optimization, Brazil, 01 – 05.

[14] Mingqi L. and Xing L.,(2010), "Genetic Algorithms Based Methodologies for Optimization Designs of RC Structures" International Conference on Intelligent System Design and Engineering Application, 13-14 Oct. 2010,1, pp.787- 790.

[15] S. Sato, K. Otori, A. Takizawa, H. Sakai, Y. Ando and H. Kawamura,(2002) "Applying genetic algorithms to the optimum design of a concert hall" Journal of Sound and Vibration (2002) 258(3), 517–526.

[16] M.Y. Raq, C. Southcombe(1998) "Genetic algorithms in optimal design and detailing ofreinforced concrete biaxial columns supported by adeclarative approach for capacity checking" Computers and Structures 69 (1998) 443±457.

[17] Bhalchandra S.A., Adsul,P.K., (2012),"Cost Optimization Of Doubly Reinforced Rectangular Beam Section" International Journal of Modern Engineering Research,Vol. 2, Issue. 5, pp3939-3942.

[18] Mohammad G. Sahab M.G, Toropov V.V, Ashour A.F,(2004)-" a hybrid genetic algorithm for structural optimization problems" Asian journal of civil engineering (building and housing) vol. 5, nos 3-4.

[19] M.G. Sahab a, A.F. Ashour b, V.V. Toropov (2005) "A hybrid genetic algorithm for reinforced concrete flat slab buildings"Computers and Structures 83 (2005) 551–559

[20] Suji D., Natesan S. C., Murugesan R. and Prabhu R. S., (2008), "Optimal Design of Fibrous Concrete Beams Through Simulated Annealing", Thammasat International Journal of Science and Technology,13(1), pp. 22-37.

[21] Villalba P., Alcala J., Yepes V., and Vidosa F. G.,(2010), "CO2 Optimization of Reinforced Concrete Cantilever Retaining Walls" 2nd International Conference on Engineering Optimization, September 6-9, 2010, Lisbon, Portugal.

[22] Perea, C., Alcala J., Yepes,V, Vidosa,F.G., Hospitaler, A., (2007), "Design of reinforced concrete bridge frames by heuristic optimization" Advances in Engineering Software xxx (2007) xxx–xxx.

[23] Vidosa F. G., Yepes V., Alcala J., Carrera M., Perea C. and Zaforteza I. P., (2008),"Optimization of Reinforced concrete structures by Simulated Annealing" Simulated Annealing, I.Tech Education and Publishing, Vienna, Austria, pp.420, Chap.15.

[24] Geem, ZW, Kim J-H, Loganathan GV.(2001)," A new heuristic optimization algorithm: harmony search", Simulation 2001; 76(2): 60-8.

[25] Geem Z.W.(2008) " Novel Derivative of Harmony Search Algorithm for Discrete Design Variables", Appl Math Comput , 199(1): 223-30.

[26] Kaveh. A, Abadi. A.S.M.,(2011), "Harmony search based algorithms for the optimum cost design of reinforced concrete cantilever retaining walls" International journal of civil Engineering, vol. 9, No. 1,pp1-8.

[27] Jahjouh,M.M.(2012) Thesis "Design Optimization of Reinforced Concrete Frames using Artificial Bee Colony Algorithm" The Islamic University of Gaza.

[28] Kennedy. J and Eberhart R.C, Particle Swarm Optimization, IEEE International Conference on Neural Networks, Perth, Australia, 1995.

[29] Khajehzadeh.M, Taha, M.R, El-Shafie.P and Eslami.M,(2010), "Economic Design of Retaining Wall Using Particle Swarm Optimization with Passive Congregation" Australian Journal of Basic and Applied Sciences, 4(11):pp 5500-5507.

[30] Nedushan A. and Varaee H., (2011), "Minimum Cost Design of Slabs using Particle Swarm Optimization with time Varying Acceleration Coefficients", World Applied Sciences Journal, 13(12), pp. 2484-2494.

[31] Saruhan.H.,(2010)"Particle Swarm Optimization for Structural Design Problems"Pamukkale Üniversitesi,Mühendislik

Bilimleri Dergisi,Cilt 16, Sayı 2, 2010, Sayfa 207-212.
[32] Leps. M., Sejnoha. M., (2003), "New approach to optimization of reinforced concrete beams" Computers and Structures 81, pp.1957-1966 .
[33] McCluskey S. and McCarthy T. J., (2009), "A particle swarm optimisation approach to reinforced concrete beam design according to AS3600", Proceedings of the First International Conference on Soft Computing Technology in Civil, Structural and Environmental Engineering, Civil- Comp Press, Madeira, Portugal, pp. 1-14.
[34] Kaveh, A., Sabzi.O., (2011), "Optimum Design of Reinforced Concrete Frames using a Heuristic Particle Swarm-Ant Colony Optimization" Proceedings of the Second International Conference on Soft Computing Technology in Civil, Structural and Environmental Engineering, Y. Tsompanakis and B.H.V. Topping, (Editors).
[35] Yang. B., Zhang. Q., (2010), "Frame sizing and topological optimization using a modified particle swarm algorithm" Second WRI Global Congress on Intelligent Systems, IEEE, Computer society.
[36] Omkar, S.N., Mudigere, D., Naik,G.N., Gopalakrishnan,S(2008), "Vector evaluated particle swarm optimization (VEPSO) for multi-objective design optimization of composite structures" Computers and Structures 86 pp. 1–14.
[37] Khajehzadeh.M, Taha, M.R, El-Shafie.A and Eslami.M,(2011), "Modified particle swarm optimization of spread footing and retaining wall" Joual of Zhejiang university-Science A(Applied physics and Engg.).
[38] Khajehzadeh.M, Eslami .M, (2012),"Gravitational search algorithm for optimization of retaining structures" Indian Journal of Science and Technology, Vol. 5 No. 1.
[39] Khajehzadeh.M, Taha, M.R, El-Shafie.A. and Eslami.M, (2012), "Optimization of Shallow Foundation Using Gravitational Search Algorithm"Research Journal of Applied Sciences Engineering and Technology 4(9):pp 1124-1130.
[40] Senouci A. B., (2000), "Preliminary Design of Reinforced Concrete Beams Using Neural Networks", Engineering Journal of University of Qatar, 13, pp.107-122.
[41] Ahmadkhanlou.F, Hojjat Adeli.H.,(2005) "Optimum cost design of reinforced concrete slabs using neural dynamics model." Engineering Applications of Artificial Intelligence 18 pp. 65–72.
[42] Saini B., Sehgal V. K. and Gambhir M. L., (2006), "Genetically optimized artificial neural networks based optimum design of singly and doubly reinforced concrete beams", Asian Journal of Civil Engineering (Building and Housing), 7(6), pp. 603-619.
[43] Babiker S.A., Adam F.M and Mohamed A.E., (2012),"Design Optimization of Reinforced concrete beams using Artificial Neural Network" International Journal of Engineering Inventions 1(8), pp. 07-13.
[44] Arslan.M.H., (2010) "An evaluation of effective design parameters on earthquake performance of RC buildings using neural networks" Engineering Structures 32 pp. 1888-1898.
[45] Rao.H.S, Babu.B.R.,(2007) "Hybrid neural network model for the design of beam subjected to bending and shear" Sadhana ,Vol. 32, Part 5, pp. 577–586.
[46] Lee. G.W., Ko. S.G.,Choi. B.H., Lee, H.C.,(2000)-" A study on the optimum design of RC Structures with discrete design variables by Fuzzy inference" vol.31, pp. 49-60.
[47] Zhang H, Li H. Multi-objective particle swarm optimization for construction time-cost tradeoff problems. Construction Management and Economics 28(1), pp. 75-88, 2010.
[48] Zamarrón-Mieza, V. Yepes, Moreno-Jiménez J.M. A Systematic Review of Application of Multi-Criteria Decision Analysis for Aging-Dam. Journal of Cleaner Production 147, pp. 217-230, 2017.
[49] Yang X.S. Nature-Inspired Metaheuristic Algorithms. Luniver Press, United Kingdom, 2008.
[50] Xiao C, Ling T, Qiu Y. Optimization of technical measures for improving high-temperature performance of asphalt–rubber mixture. Journal of Modern Transportation, 21(4), pp. 273–280, 2013.
[51] Wahab MNA, Meziani SN, A Atyabi . A Comprehensive Review of Swarm Optimization Algorithms. 1, pp. 1-36, 2015.
[52] Uzlu E, Kankal M, Akpınar A, Dede T. Estimates of energy consumption in Turkey using neural Networks with the teaching learning-based optimization algorithm. Energy, 75, pp. 295-303, 2014.
[53] Torres-Machi, Yepes V, Alcalá J, Pellicer E. Optimization of high-performance concrete structures by variable neighborhood search. International Journal of Civil Engineering, Transaction A: Civil Engineering, 11(2), pp. 90-99, 2013.
[54] Topal U, DedeT, Öztürk H.T. Stacking Sequence Optimization for Maximum Fundamental Frequency of Simply Supported Anti-symmetric Laminated Composite Plates using Teaching–Learning- Based Optimization. KSCE Journal of Civil Engineering 266, pp. 2281- 2288, 2017.
[55] Tonne V.R., Mohite P.M. Optimization and Improvement in Stability of Counterfort Retaining Wall with Relief Shelf. IJRET: International Journal of Research in Engineering and Technology 4(4), pp. 447-45, 2015.
[56] Thamaraikannan B, Thirunavukkaras V. Design Optimization of Mechanical Component Using an Enhanced Teaching-Learning Based Optimization Algorithm with Differential Operator. Mathematical Problems in Engineering, Hindawi Publishing Corporation, pp. 1-10, 2014.
[57] Tavana M, abtahi AR, Khalili-Damghani K. A new multi-objective multi-mode model for solving pre-emptive time–cost–quality trade-off project scheduling problems. Expert Systems with Applications 4, pp. 1830-1846, 2014.
[58] Talaslioglu T. Multi-objective Design Optimization of Grillage Systems according to LRFD-AISC. Advances in Civil Engineering 211, pp.1-24, 2011.
[59] Storn R, Price K. Differential evolution –a simple and efficient heuristic for global optimisation over continuous spaces. J Global Optim 11, pp. 341-359, 1997.