INSTITUTE OF CONCRETE SCIENCE AND TECHNOLOGY (ICITECH)

POLYTECHNIC UNIVERSITY OF VALENCIA

SUSTAINABLE CONCRETE (HORSOST)

ICITECH

The Institute of Concrete Science and Technology ICITECH is a research institute where several lines of work are conducted. The main aim is the concrete research from a wide range of aspects: a basic character, ranging from the constituent materials, the manufacturing process or physicochemical behaviour (focus on the technological, chemical or environmental aspects) to the secondary raw materials utilization, and others more applied, including the study of concrete structures behaviour, the practical rules for the design or rehabilitation, and the construction aspects.

The proposal is to encourage and promote quality research by conducting R&D projects. As a result, the technology and knowledge is transferred to companies and industrial partners.

Director: Jordi Paya Bernabeu

Creation: January 2005

Professors Dr affiliated with the Institute: 29

Total researchers: 59

Technical Staff: 5

Research Areas:

- Advanced Materials
- Sustainability
- Monitoring and Maintenance
- Experimental Structural Analysis
- Numerical Structural Analysis
- Sustainable Concrete Optimization

Concrete Laboratory Testing

Material and Chemical Laboratory

Numerical Analysis

HORSOST

HORSOST is a research project financially supported by the Spanish Ministry of Science and Innovation (Research Project BIA2011-23602). The main objective of this research project (HORSOST) is to develop a methodology to establish efficient design criteria for non-conventional concrete structures that maximize their contribution to sustainability. The project focuses on high strength concrete, fibre-reinforced concrete and self-compacting concrete. Innovations in non-conventional concretes give researchers a new horizon in the sustainability field, due to its increase in performance and durability in conventional concrete.

This study develops low carbon innovations by studying all the phases of the concrete structures life cycle (manufacturing and materials delivery, construction methods, use and exploitation, maintenance, dismantlement and reutilization). The contribution of concrete structures to sustainability is done from many aspects: energy and natural resources savings, environmental, social and economic.

We have explored a research area related to blended cements. Using waste products to replace Portland cement, which is the main contributor to CO_2 emissions in concrete production, reduces the embodied greenhouse gas (GHG) emissions. Some concrete life cycle studies are being developed, taking into account durability and the reduction in CO_2 capture by hardened concrete carbonation.

Optimization methods are used to find new efficient concrete structures, according to the sustainability maximization. It enables us to achieve significant reductions in cost and CO_2. As a result, efficient structures databases are generated. Then, the non-trivial information is extracted applying Knowledge Discovery from Databases (KDD) techniques. Finally, extracted knowledge should be transferred to scientific community for subsequent practical application by the designers.

The main lines of work are:

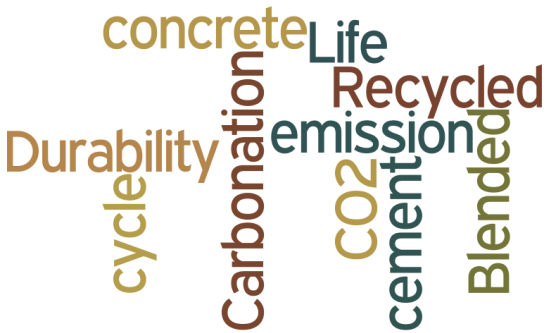
- Heuristic optimization methods to provide efficient structures.
- Approach the use of high strength concrete, fibre-reinforced concrete and self-compacting concrete to sustainability field.
- New designing criteria according to the sustainability maximization.

LIFE CYCLE GREENHOUSE GAS EMISSIONS OF BLENDED CEMENT CONCRETE INCLUDING CARBONATION AND DURABILITY

Tatiana García-Segura; Víctor Yepes; Julián Alcalá (2013)

The International Journal of Life Cycle Assessment. ISSN: 0948-3349

Purpose. Blended cements use waste products to replace Portland cement, the main contributor to CO_2 emissions in concrete manufacture. Using blended cements reduces the embodied greenhouse gas emissions; however, little attention has been paid to the reduction in CO_2 capture (carbonation) and durability. The aim of this study is to determine if the reduction in production emissions of blended cements compensates for the reduced durability and CO_2 capture. **Methods.** This study evaluates CO_2 emissions and CO_2 capture for a reinforced concrete column during its service life and after demolition and reuse as gravel filling material. Concrete depletion, due to carbonation and the unavoidable steel embedded corrosion, is studied, as this process consequently ends the concrete service life. Carbonation deepens progressively during service life and captures CO_2 even after demolition due to the greater exposed surface area. In this study, results are presented as a function of cement replaced by fly ash (FA) and blast furnace slag (BFS). **Results and discussion.** Concrete made with Portland cement, FA (35 % FA), and BFS blended cements (80 % BFS) captures 47, 41, and 20 % of CO_2 emissions, respectively. The service life of blended cements with high amounts of cement replacement, like CEM III/A (50 % BFS), CEM III/B (80 % BFS), and CEM II/B-V (35 % FA), was about 10 % shorter, given the higher carbonation rate coefficient. Compared to Portland cement and despite the reduced CO_2 capture and service life, CEM III/B emitted 20 % less CO_2 per year. **Conclusions.** To obtain reliable results in a life cycle assessment, it is crucial to consider carbonation during use and after demolition. Replacing Portland cement with FA, instead of BFS, leads to a lower material emission factor, since FA needs



Heuristic optimization model for infrastructure asset management

Cristina Torres-Machí; Eugenio Pellicer; Víctor Yepes; Alondra Chamorro (2013)

The International Journal of Life Cycle Assessment. July 2013

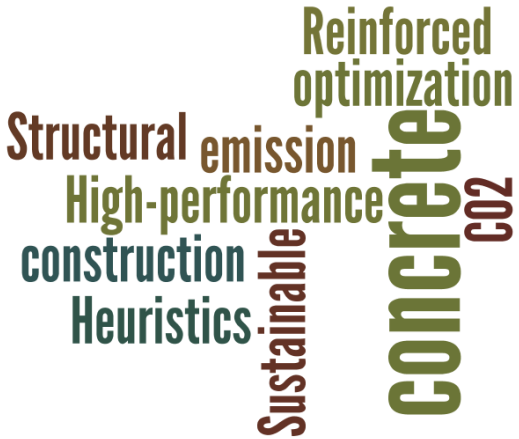
In developed countries, the need of infrastructure maintenance is becoming an important issue because their infrastructures have been built up progressively over the last 100 years or longer. Moreover, users are increasingly demanding in in terms of quality, comfort, and safety. Under this scenario, infrastructure managers seek to optimize each monetary unit invested in maintenance, thus ensuring that funds allocated to the best alternative. This paper presents a heuristic model for solving the budget allocation problem with the implementation of a Simulated Annealing (SA) algorithm. An illustrative example is undertaken, analyzing the effect of budgetary restrictions in infrastructure performance. It can be concluded that infrastructure performance show a good parabolic correlation with available budget.

Optimization Of High-Performance Concrete Structures by Variable Neighborhood Search

Cristina Torres Machi; Víctor Yepes; Julián Alcalá; Eugenio Pellicer (2013)

International Journal of Civil Engineering, 11(2):90-99 . ISSN: 1735-0522

This paper describes a methodology in designing high-performance concrete for simply supported beams, using a hybrid optimization strategy based on a variable neighborhood search threshold acceptance algorithm. Three strategies have been applied to discrete optimization of reinforced concrete beams: Variable Neighborhood Descent (VND), Reduced Neighborhood Search (RNS) and Basic Variable Neighborhood Search (BVNS). The problem includes 14 variables: two geometrical; one material type; one mix design; and 10 variables for the reinforcement setups. The algorithms are applied to two objective functions: the economic cost and the embedded CO_2 emissions. Firstly, this paper presents the application of these three different optimization strategies, which are evaluated by fitting the set of solutions obtained to a three-parameter Weibull distribution function. The Variable Neighborhood Descent with Threshold Accepting acceptance strategy algorithm (VND-TA) results as the most reliable method. Finally, the study presents a parametric study of the span length from 10 to 20 m in which it can be concluded that economic and ecological beams show a good parabolic correlation with the span length.

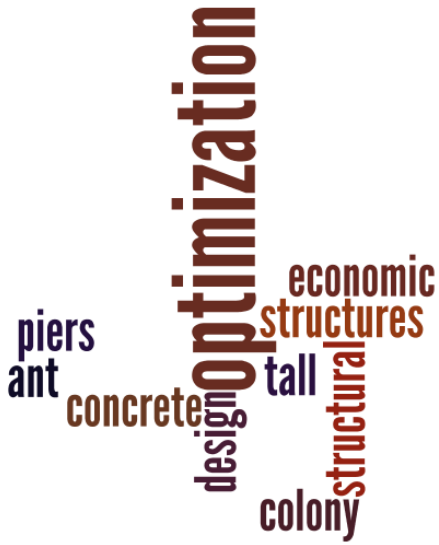


A PARAMETRIC STUDY OF OPTIMUM TALL PIERS FOR RAILWAY BRIDGE VIADUCTS

Francisco J. Martinez-Martin; Fernando Gonzalez-Vidosa; Antonio Hospitaler; Victor Yepes (2013)

Structural Engineering and Mechanics. Volume 45, Issue ,6, 2013, pp.723-740

This paper presents a parametric study of reinforced concrete bridge tall piers with hollow, rectangular sections. Such piers are typically used in railway construction of prestressed concrete viaducts. Twenty one different piers have been studied with seven column heights of 40, 50, 60, 70, 80, 90 and 100 m and three types of 10-span continuous viaducts, whose main span lengths are 40, 50 and 60 m. The piers studied are intermediate columns placed in the middle of the viaducts. The total number of optimization design variables varies from 139 for piers with column height of 40 m to 307 for piers with column height of 100 m. Further, the results presented are of much value for the preliminary design of the piers of prestressed concrete viaducts of high speed railway lines.



Design of prestressed concrete precast road bridges with hybrid simulated annealing

José V. Martí; Fernando Gonzalez-Vidosa; Víctor Yepes; Julián Alcalá (2013)

Engineering Structures, *48*:342-352. DOI:10.1016/j.engstruct.2012.09.014. ISSN: 0141-0296

This paper describes one approach to the analysis and design of prestressed concrete precast road bridges, with double U-shaped cross-section and isostatic spans. The procedure used to solve the combinatorial problem is a variant of simulated annealing with a neighborhood move based on the mutation operator from the genetic algorithms (SAMO). This algorithm is applied to the economic cost of these structures at different stages of manufacturing, transportation and construction. The problem involved 59 discrete design variables for the geometry of the beam and the slab, materials in the two elements, as well as active and passive reinforcement. The parametric study showed a good correlation for the cost, geometric and reinforcement characteristics with the span length, which can be useful for the day-to-day design of PC precast bridges. A cost sensitivity analysis first indicates that a maximum 20% rise in steel costs leads to an 11.82% increase in the cost, while a 20% rise in concrete costs increases the cost up to 4.20%, namely 2.8 times less. The analysis also indicated that the characteristics of the cost-optimized bridges are somewhat influenced by different economic scenarios for steel and concrete costs. Finally, there is a growth in the volume of concrete when the steel cost rises; surprisingly, the variation in the volume of concrete is almost insensitive to its rising price.

MULTI-OBJECTIVE OPTIMIZATION DE SIGN OF BRIDGE PIERS WITH HYBRID HEURISTIC ALGORITHMS

Francisco J. Martinez-Martin; Fernando Gonzalez-Vidosa; Antonio Hospitaler; Víctor Yepes (2012)

Journal of Zhejiang University-SCIENCE A (Applied Physics & Engineering, 13(6):420-432. DOI: 10.1631/jzus.A1100304. ISSN 1673-565X (Print); ISSN 1862-1775

This paper describes one approach to the design of reinforced concrete (RC) bridge piers, using a three-hybrid multiobjective simulated annealing (SA) algorithm with a neighborhood move based on the mutation operator from the genetic algorithms (GAs), namely MOSAMO1, MOSAMO2 and MOSAMO3. The procedure is applied to three objective functions: the economic cost, the reinforcing steel congestion and the embedded CO_2 emissions. Additional results for a random walk and a descent local search multi-objective algorithm are presented. The evaluation of solutions follows the Spanish Code for structural concrete. The methodology was applied to a typical bridge pier of 23.97 m in height. This example involved 110 design variables. Results indicate that algorithm MOSAMO2 outperforms other algorithms regarding the definition of Pareto fronts. Further, the proposed procedure will help structural engineers to enhance their bridge pier designs

CO_2-Optimization Design of Reinforced Concrete Retaining Walls based on a VNS-Threshold Acceptance Strategy

Víctor Yepes; Fernando Gonzalez-Vidosa, Julian Alcala; Pere Villalba (2012)

Journal of Computing in Civil Engineering ASCE, 26 (3):378-386. DOI: 10.1061/(ASCE)CP.1943-5487.0000140. ISNN: 0887-3801

This paper describes one approach to a methodology to design reinforced concrete cantilever retaining walls for road construction, using a hybrid multistart optimization strategic method based on a variable neighborhood search threshold acceptance strategy (VNS-MTAR) algorithm. This algorithm is applied to two objective functions: the embedded CO_2 emissions and the economic cost of reinforced concrete walls at different stages of materials production, transportation and construction. The problem involved 20 design variables: four geometric variables (thickness of the stem and the base slab, as well as the toe and heel lengths), four material types, and 12 variables for the reinforcement set-up. Results first indicate that embedded emissions and cost are closely related, and that more environmentally-friendly solutions than the lowest cost solution are available at a cost increment of less than 1.28%. The analysis also indicated that reducing costs by one euro could save up to 2.28% kg in CO_2 emissions. Finally, the cost-optimized walls require about 4.8% more concrete than the best environmental ones, which need 1.9% more steel.

Heuristic optimization of reinforced concrete road vault underpasses

Alfonso Carbonell Lombardero; Fernando Gonzalez Vidosa; Víctor Yepes Piqueras (2011)

Advances in Engineering Software, 42(4): 151-159. ISSN: 0965-9978

This paper aims at the automatic design and cost minimization of reinforced concrete vaults used in road construction. This paper presents three heuristic optimization methods: the multi-start global best descent local search (MGB), the meta-simulated annealing (SA) and the meta-threshold acceptance (TA). Penalty functions are used for unfeasible solutions. The structure is defined by 49 discrete design variables and the objective function is the cost of the structure. All methods are applied to a vault of 12.40 m of horizontal free span, 3.00 m of vertical height of the lateral walls and 1.00 m of earth cover. This paper presents two original moves of neighborhood search and an algorithm for the calibration of SA-TA algorithms. The MGB algorithm appears to be more efficient than the SA and the TA algorithms in terms of mean results. However, the SA outperforms MGB and TA in terms of best results. The optimization method indicates savings of about 10% with respect to a traditional design.

A PARAMETRIC STUDY OF OPTIMUM ROAD FRAME BRIDGES BY THRESHOLD ACCEPTANCE

Cristian Perea; Víctor Yepes; Julián Alcalá; Antonio Hospitaler; Fernando González-Vidosa (2010)

Indian Journal of Engineering & Materials Sciences, 17(6):427-437. ISSN: 0971-4588

This paper examines the economic optimization of reinforced concrete road frame bridges by threshold acceptance. The formulation of the problem includes 50 discrete variables: three geometrical ones, three types of concrete and 44 reinforcement bars and bar lengths. Design loads are in accordance with the national codes for road bridges. An internal matrix method program computes the stress resultants and envelopes of the frame bridges. The evaluation module includes the ultimate limit state of fatigue plus other commonly specified limit states of service and ultimate flexure, shear and deflections. Solutions are evaluated following the Spanish code for structural concrete. This study reviews the main factors affecting the design of frame bridges. The study then presents a parametric study of commonly used road frame bridges from 8 to 16 m in horizontal span for different fills and earth covers conditions. The evolution of the total, concrete and steel cost is examined with regard to the key parameters, resulting in practical rules of thumb for optimum frames. Finally, it is shown that the steel-to-concrete cost has a fair influence on the characteristics of the optimum road frame bridges.

On the Weibull cost estimation of building frames designed by simulated annealing

Alfonso Carbonell Lombardero; Fernando Gonzalez Vidosa; Víctor Yepes Piqueras (2010)

Advances in Engineering Software, 42(4): 151-159. ISSN: 0965-9978

This paper proposes a general methodology to determine the number of numerical tests required to provide a solution for a heuristic optimization problem with a user-defined accuracy as compared to a global optimal solution. The methodology is based on the extreme value theory and is explained through a problem of cost minimization for reinforced concrete building frames. Specifically, 1000 numerical experiments were performed for the cost minimization of a two-bay and four-floor frame using the Simulated Annealing (SA) algorithm. Analysis of the results indicates that (a) a three-parameter Weibull distribution function fits the results well, (b) an objective and general procedure can be established to determine the number of experiments necessary to solve an optimization problem with a heuristic which generates independent random solutions, and (c) a small number of experiments is enough to obtain good results for the structural engineer

Heuristic optimization of RC bridge piers with rectangular hollow sections

Francisco J. Martínez; Fernando González-Vidosa; Antonio Hospitaler; Víctor Yepes (2010)

Computers & Structures, 88: 375-386. ISSN:0045-7949.

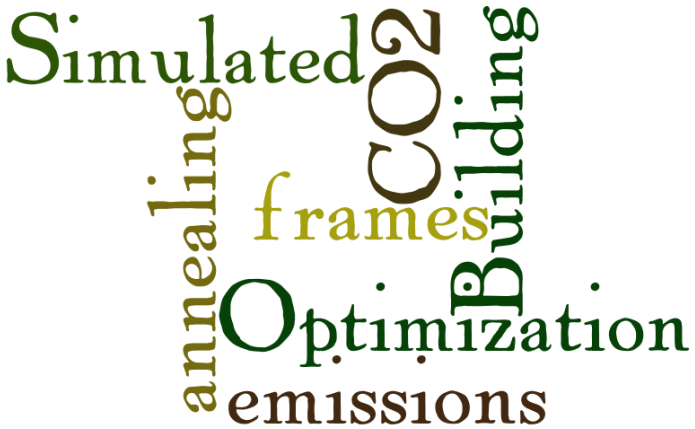
This paper deals with the economic optimization of reinforced concrete (RC) bridge piers with hollow rectangular sections and describes the efficiency of three heuristic algorithms: two new variants of the ant colony optimization (ACO) algorithm, the genetic algorithm (GA) and the threshold acceptance (TA) algorithm. The GA and TA are used for comparison with the new ACO algorithms. The total number of variables is 95. All variables are discrete in this analysis. The calibration of the new ACO algorithm recommended a 250-member ant population and 100 stages. The best solution costs 69,467 euros, which means savings of about 33% as compared to experience-based design. Finally, results indicate that the new ACO algorithms are potentially useful for optimizing the costs of real RC structures.

CO_2-OPTIMIZATION OF REINFORCED CONCRETE FRAMES BY SIMULATED ANNEALING

Ignacio Paya-Zaforteza; Víctor Yepes; Antonio Hospitaler; Fernando González-Vidosa (2009)

Engineering Structures, 31: 1501-1508. ISSN: 0141-0296

This paper describes a methodology to design reinforced concrete (RC) building frames based on minimum embedded CO_2 emissions. The design involves optimization by a simulated annealing (SA) algorithm applied to two objective functions, namely the embedded CO_2 emissions and the economic cost of RC framed structures. The evaluation of solutions follows the Spanish Code for structural concrete. The methodology was applied to six typical building frames with 2, 3 and 4 bays and up to 8 floors. The largest example has 153 design variables and a combinatorial solution space of 10^{232}. Results from the SA algorithm application indicate that embedded emissions and cost are closely related and that more environmentally-friendly solutions than the lowest cost solution are available at a cost increment which is quite acceptable in practice. Further, the best solutions for the environment are only at the most 2.77% more expensive than the best cost solutions. Alternatively, the best cost solutions increase CO_2 emissions by 3.8%. Finally, the methodology described will enable structural engineers to mitigate CO_2 emissions in their RC structural designs.



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