



CEDEX

TECHNICAL
AND SCIENTIFIC ACTIVITIES

2019



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AND SCIENTIFIC ACTIVITIES
2019**



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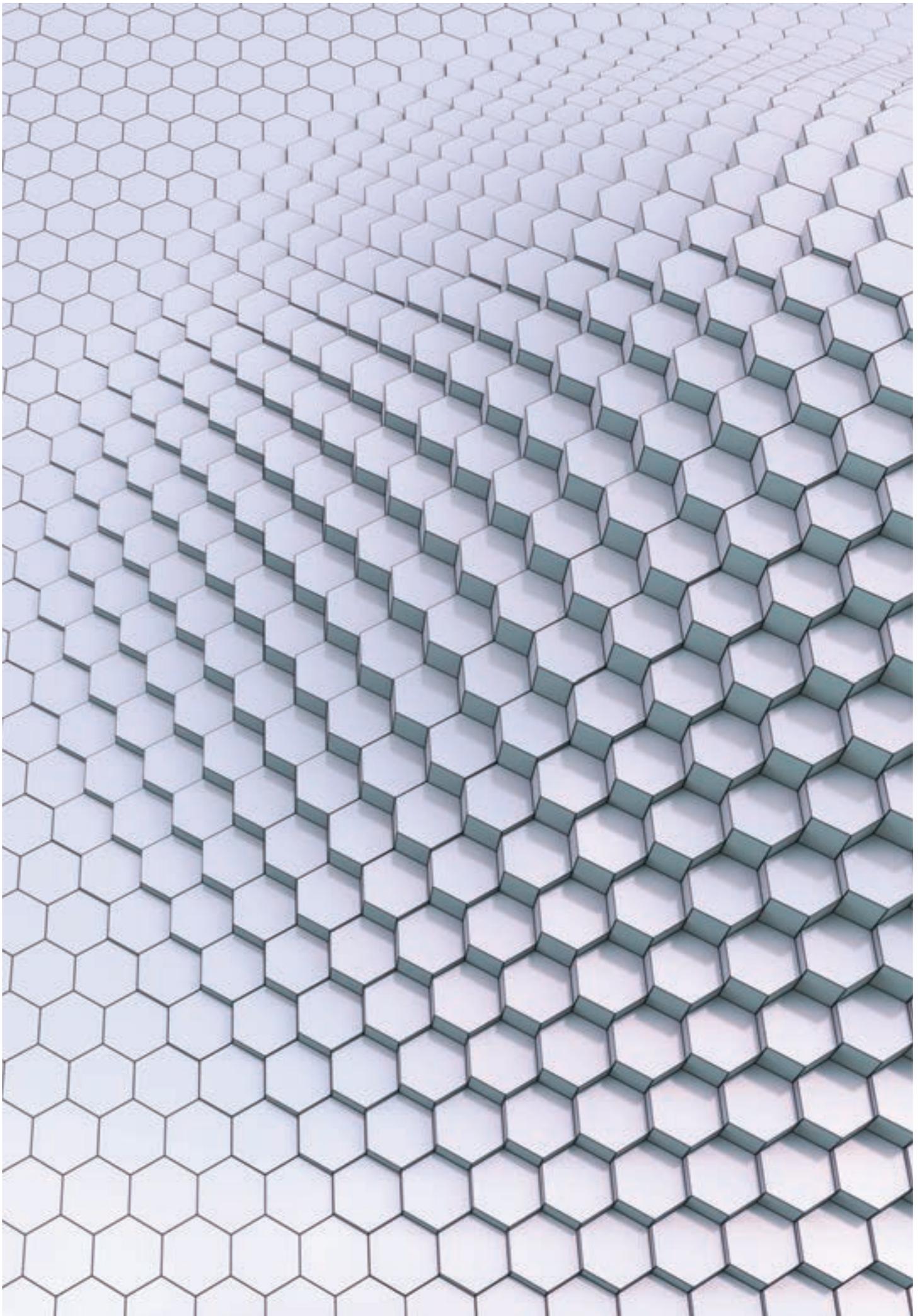
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FOREWORD

PEDRO SAURA GARCÍA

Secretary of State for Transport,
Mobility and Urban Agenda

In a globalized and changing environment, the acquisition and renewal of knowledge through research is one of the fundamental assets for the development of any society, and one of the fundamental levers for driving economic growth and improving social welfare worldwide. That is why promoting research and innovation must be one of the inspiring principles of any public policy. Moreover, talent as a value added to these potentials and to such quest for new knowledge emerges as the element that enhances the final result.

The Centre for Studies and Experimentation in Public Works (CEDEX), an agency created in 1957, is a case in point on how to enrich this search for ideas and alternatives by using some of the best public employees, updating constantly knowledge, and responding to the challenges of the present and the future: the new and growing needs of the population concentration in cities and its counterpart of the demographic challenge in other areas of the territory, the decarbonization of the productive system, the adaptation to climate change, and the development and implementation of a sustainable, safe and connected mobility that guarantees the adequacy of infrastructures and services to the economic, social and environmental challenges, and improves social cohesion.

All this is within the commitment of the agency to consolidating its strategy by joining the “vectors of change” aligned with the fulfillment of the United Nations Sustainable Development Goals (SDGs), as part of the 2030 Agenda, so as to tackle poverty, inequality and exclusion, modernizing the economy, fighting climate change and promoting the digital transformation.

This last challenge of the so-called digital transformation and its great impact on all areas, especially on mobility, housing and public health, both in large and medium-sized cities and in rural environments, requires a new way of addressing issues and designing solutions.

Likewise, CEDEX focuses, as a research agency, on anticipating emerging needs and trends, playing an active participation, and looking out for the advances in the international panorama, with an intense communication with all the agents involved.

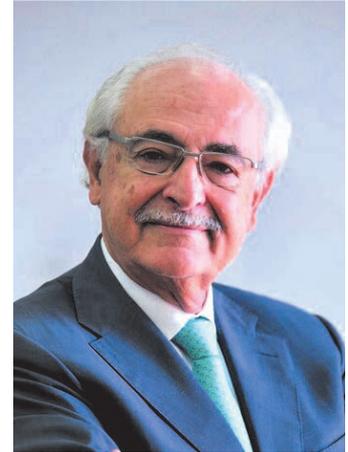
All these tasks have been materialized in its *Strategic Plan for 2020-2022*. In it, CEDEX fleshes out ambitious proposals to meet the challenges ahead, following the new guidelines of the Ministry for Transport, Mobility and Urban Agenda (MITMA), and the Ministry for Ecological Transition and Demographic Challenge (MITERD/MITECO).

In short, the “Safe, Sustainable and Connected Mobility Strategy” promoted by MITMA constitutes the general framework for advancing mobility policies in a line of reorientation of the concept of mobility as a citizen’s right, and a tool for social cohesion, economic growth and competitiveness.

Equally important, and from an environmental sustainability point of view, on 21 January 2020 the Council of Ministers approved the Government’s agreement on a Declaration on the Climate and Environmental Emergency in Spain, thus responding to the general consensus of the scientific community that calls for urgent action to safeguard the environment, health and safety of citizens. This also shows the commitment and priority given to this agenda in a context of great economic and social risks due to the impacts of climate change, as recognized in the annual report of the Davos Forum, which refers to it as one of the greatest threats to the global economy, or in the European Commission’s Green Deal.

Within this framework, CEDEX has a crucial role to play in accelerating innovation, striving for the adaptation and strengthening of its resources, bringing the best out of its talented professionals, improving its efficiency and bolstering R&D&I, all with the aim to provide a better service to the sector concerned and, thereby, to society as a whole.





PREAMBLE

JOSÉ TRIGUEROS RODRIGO

Director of CEDEX

As with previous years, the CEDEX Annual Activity Report for 2019 gives a graphic and detailed account of the wide range of activities carried out by the Agency in all the thematic areas of civil engineering for which is, by enabling statutes, responsible: Water, Structures and Materials, Ports and Coasts, Transport and Mobility, Roads, Sustainability, Ecological Transition, Geotechnics, Railway Interoperability, Historical Heritage of Public Works, Circular Economy, and Knowledge Transfer.

Divided into four large blocks (institutional information, outstanding facilities, relevant projects, and structure by centres and laboratories), this yearbook has sought to visualise in particular a set of outstanding facilities (19) and relevant projects (33) which, due to their quality and innovation, deserve to be highlighted.

On the other hand, CEDEX has followed a marked pattern of continuity in its day-to-day activities, promoting a considerable number of technical-scientific projects and activities, as reflected in, among other things, the issuing of a total of 268 technical reports, a figure slightly higher than that of 2018.

Beyond the Agency's ordinary activities in 2019, it's worth noting the temporary coverage of 49 senior positions to develop specific research projects. This has certainly invigorated CEDEX's human capital, which is by far its most valuable strategic asset.

On another front, it should be noted that during this period work has continued to modernize the legal-institutional framework of CEDEX, through the updating of its statutes, which date from 2002. Linked to this, it's the need to strengthen, in its capacity as an autonomous public agency, its status as a means of its own. This would undoubtedly let it optimise its management and contracting

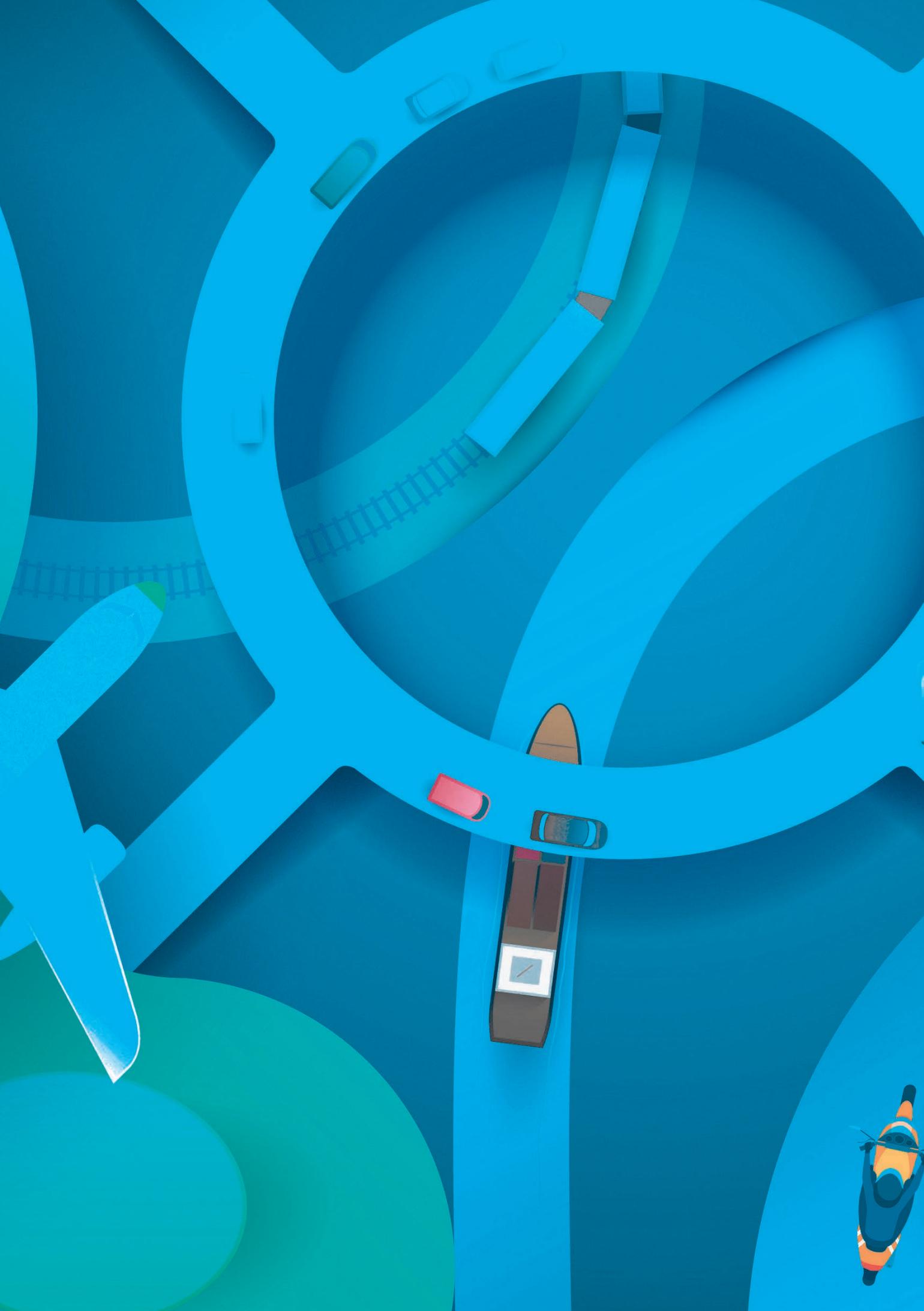
capacities concerning assignments given by other institutions in both the public and private sectors.

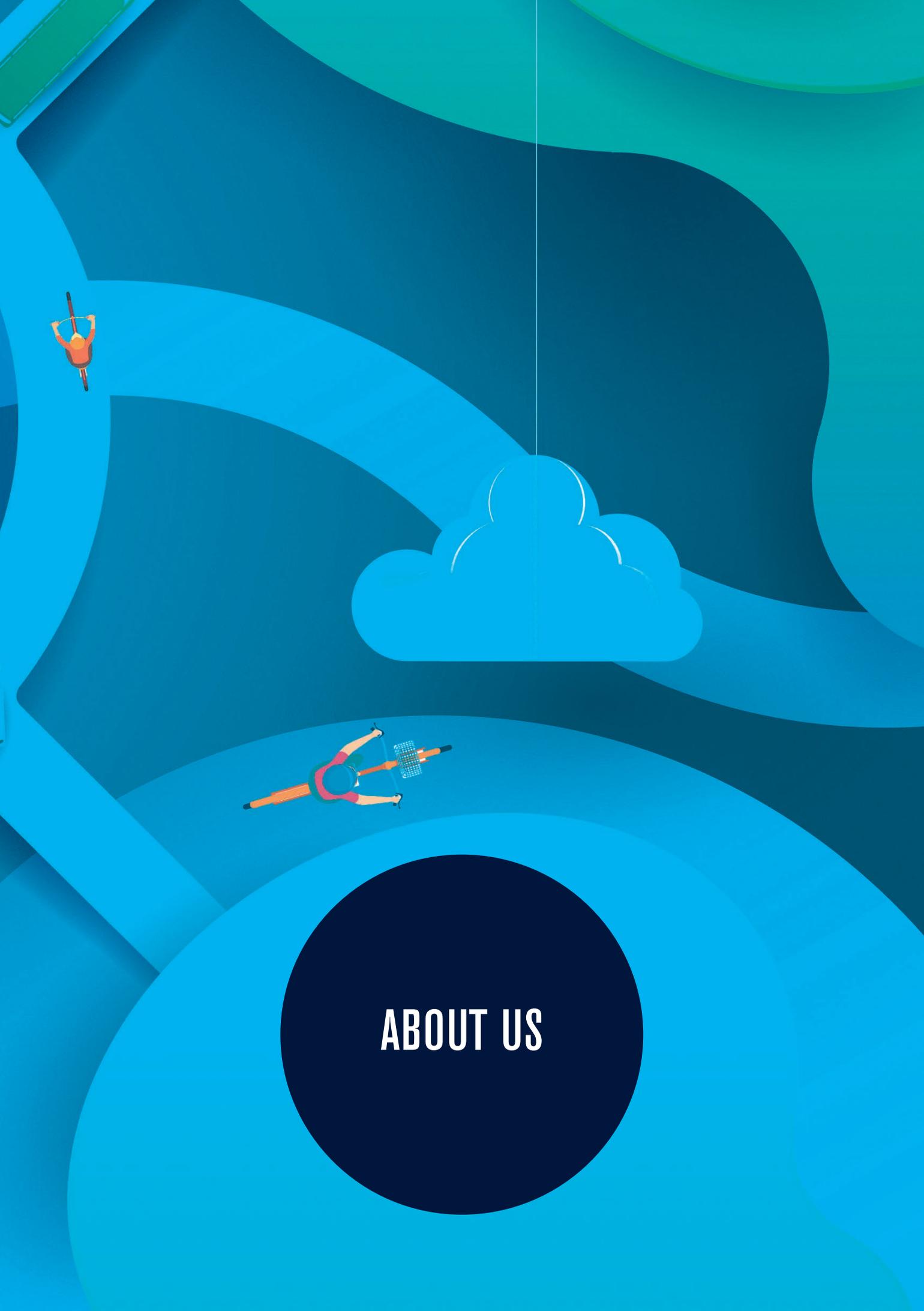
This effort to improve CEDEX's institutional framework also includes the elaboration of its *Strategic Plan for 2020-2022* which, hinging on innovation in the different fields of civil engineering, is a fundamental instrument to provide the best public service to society as a whole.

Looking to the future, CEDEX's strategic projection is to buttress its position as a thriving centre for innovation in a context dominated by the unavoidable challenges posed by digitalization, on the one hand, and the great transformations that adaptation to climate change –and sustainable, safe and connected mobility– will require, on the other.

At this crossroads, the extension of technological derivatives such as artificial intelligence, society 4.0, connectivity, Big Data and Smart Data, 5G networks, digital infrastructures, intelligent networks, Blockchain technology, etc., and their use to combat the effects of climate change, anticipate a future that will be green or not, since the current climate emergency situation demands it. In a change of era such as the present one, the dynamics of combining innovation and sustainable development will guide CEDEX's own work synergies in order to guarantee the improvement of people's lives.

To sum up, the anticipation of this confluence of the digital and green agendas, which will bring about structural changes, if it's conceived as a window of opportunity, should allow CEDEX to play a key role by clearly betting on technology and innovation and, of course, by underscoring the work, dedication and professionalism of its human teams, true architects of the success of an ambitious project for the future.





ABOUT US



ASSIGNMENTS AND FUNCTIONS

The Centre for Studies and Experimentation in Public Works (CEDEX) is an autonomous public agency, instrument of the General State Administration, among those contemplated in section 1.a) of Article 84 of Law 40/2015, of 1 October, on the Legal Regime of the Public Sector, organically assigned to the Ministry for Transports, Mobility and Urban Agenda (MITMA), through the Secretary of State for Transports, Mobility and Urban Agenda, and with functional dependence of the Ministry for Transports and the Ministry for Ecological Transition and Demographic Challenge (MITERD/MITECO), within the framework of their respective competencies.

The Agency was created by Decree of 23 August 1957. Its Statutes were approved by Royal Decree 1136/2002, of 31 October and modified by Royal Decrees (RD): RD 591/2005, of 20 May; RD 364/2009, of 20 March, and RD 582/2011, of 20 April.

Also, by Order of 5 November 1987, of the Ministry of Relations with the Courts and of the Government Secretariat, CEDEX is declared, for the purposes indicated in RD 2515/1986, of 21 November, as Public Research Centre. It's legally recognized as an autonomous research agency, in accordance with the provisions of RD 574/1997, of 18 April (modified by RD 560/2001, of 25 May).

It holds the status of agent of execution in the Spanish System of Science, Technology and Innovation in accordance with article 3.4 of Law 14/2011, of 1 June, on

Science, Technology and Innovation. In accordance with the provisions of the First Additional Provision in relation to article 13 of the aforementioned Law, the Centre of Studies and Experimentation for Public Works (CEDEX), as research agency of the General State Administration under the Ministry for Transports, Mobility and Urban Agenda, usually performs research activity.

The functions it performs are established by Royal Decree 1136/2002, of 31 October, which approved the Statutes of the Centre for Studies and Experimentation in Public Works, and can be grouped into:

- Specialized and high-level technical assistance, often based on testing and experimentation on unique equipment and facilities
- R&D&C in the field of public works, sustainable and connected mobility, environment and climate change
- Training, dissemination and knowledge transfer

The Agency meets other demands for activity from both public administrations and the private sector, maintains close collaboration ties with similar institutions in other countries in joint programs of applied research and maintains a continued presence in the international arena, within the framework of the Spanish Cooperation for Development Assistance.

GOVERNING BODIES



COUNCIL

Chaired by the Secretary of State for Transport, Mobility and Urban Agenda of the Ministry for Transport, the Council is the body that knows and guides the activities of the Agency. In accordance with Royal Decree 1136/2002 of 31 October adopting the Statute of the Centre for Studies and Experimentation in Public Works, published in the BOE of 8 November, and modified by royal decrees: 591/2005 of 20 May; 364/2009, of 20 March; 638/2010, of 14 May; and 582/2011, of April 20.

STEERING COMMITTEE

It's the body that assists the Director in the coordination and administration of the Agency. It consists of:

The President

The Director of CEDEX

Members

The Director of the Centre for Hydrographic Studies
The Director of the Centre for Studies on Ports and Coasts
The Director of the Centre for Transport Research
The Director of the Centre for Studies on Applied Techniques
The Director of the Central Laboratory for Structures and Materials
The Director of the Geotechnical Laboratory
The Director of the Railway Interoperability Laboratory
The Secretary of CEDEX

Secretary

The Head of External Relations and Commercial Activities



CEDEX Steering Committee.



SECRETARIAT

HUMAN RESOURCES

The mission of CEDEX is to help solve both traditional and emerging problems of Transport and Mobility, Water, Structures, Materials, Geotechnics, Environment and Climate Change, providing highly specialized services, contributing to the advancement of the knowledge applied through the development of research works, participating in international working groups and networks, and serving as an introduction and dissemination channel for innovation and early application of generic technologies in the aforementioned fields of activity.

The exercise of these functions requires a workforce of specific characteristics supported by a set of first level

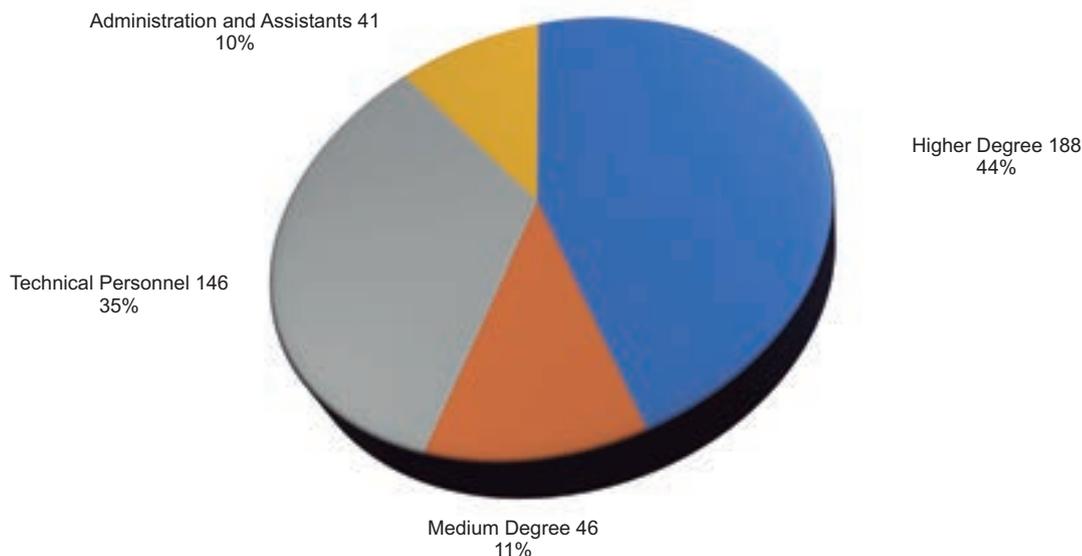
technological resources. As characteristic aspects of the Agency's personnel, we must emphasize the vocational component for striving, with the aim of continuous improvement in a field of specialization, which goes together with the flexibility required to respond to emerging needs, as well as the necessary high scientific and technical specialization.

An additional characteristic note is the multidisciplinary integration in the CEDEX teams of professionals with different backgrounds: engineering sciences and other technical activities, earth sciences and basic science, which provide complementary visions in the study of increasingly complex issues linked to aspects of planning, development and management in the fields of transport and mobility, water, environment and climate change.

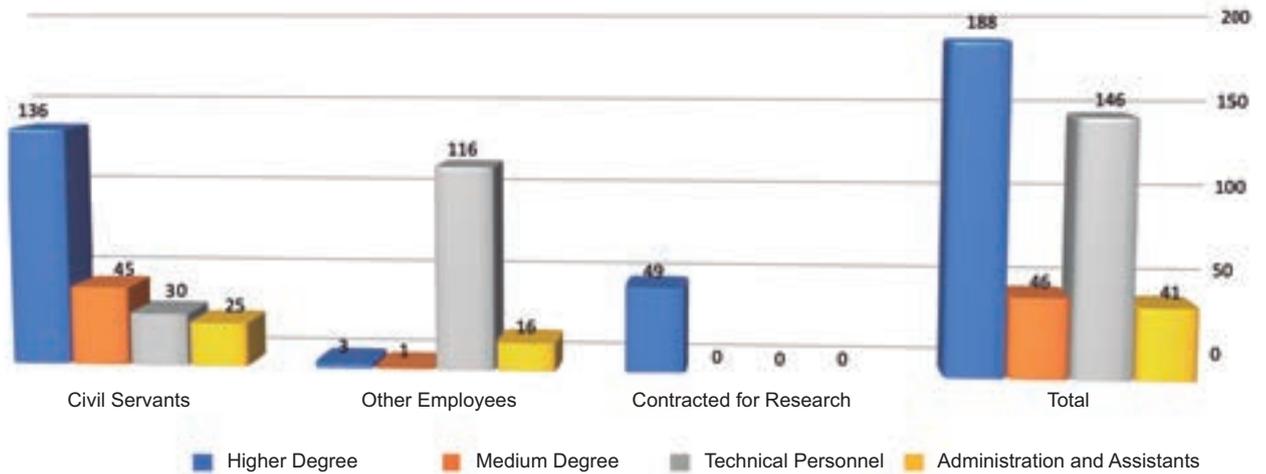
The need for sustained incorporation of personnel should also be underscored, as it ensures the essential continuity in knowledge management and the best use of CEDEX capabilities.

| PERSONNEL BY CATEGORY AND QUALIFICATION ON 31-12-2019 | | | | | | |
|---|---------------|----------------|-----------------|-------------------------|------------|-------------|
| | | Civil Servants | Other Employees | Contracted for Research | Total | % |
| Degree | Higher Degree | 136 | 3 | 49 | 188 | 44% |
| | Medium Degree | 45 | 1 | 0 | 46 | 11% |
| Technical Personnel | | 30 | 116 | 0 | 146 | 35% |
| Administration and Assistants | | 25 | 16 | 0 | 41 | 10% |
| TOTAL | | 236 | 136 | 49 | 421 | 100% |

PERSONNEL BY QUALIFICATION

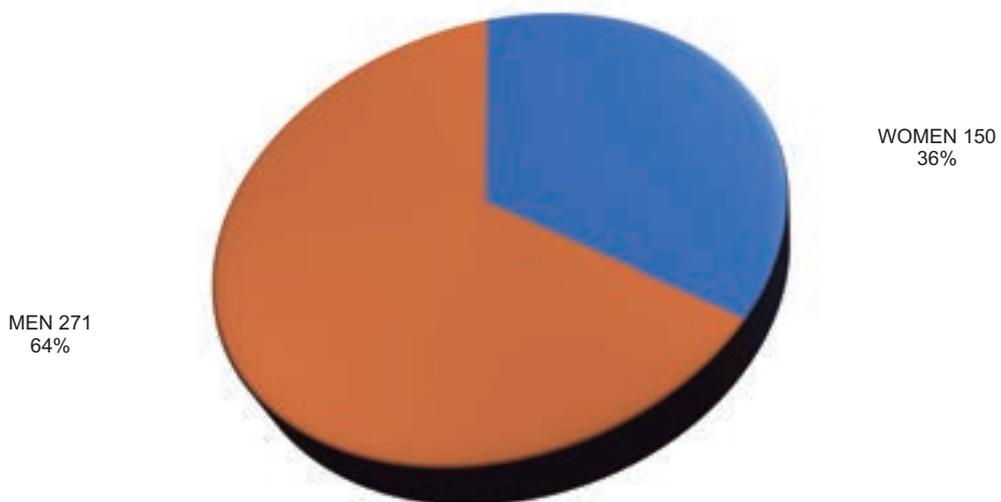


PERSONNEL BY CATEGORY AND QUALIFICATION



| PERSONNEL BY GENDER ON 12- 31-2019 | | | | | | |
|------------------------------------|---------------|------------|------------|------------|------------|------------|
| | | Women | | Men | | Total |
| Degree | Higher Degree | 75 | 40% | 113 | 60% | 188 |
| | Medium Degree | 16 | 35% | 30 | 65% | 46 |
| Technical Personnel | | 39 | 27% | 107 | 73% | 146 |
| Administration and Assistants | | 20 | 49% | 21 | 51% | 41 |
| TOTAL | | 150 | 36% | 271 | 64% | 421 |

GENDER DISTRIBUTION

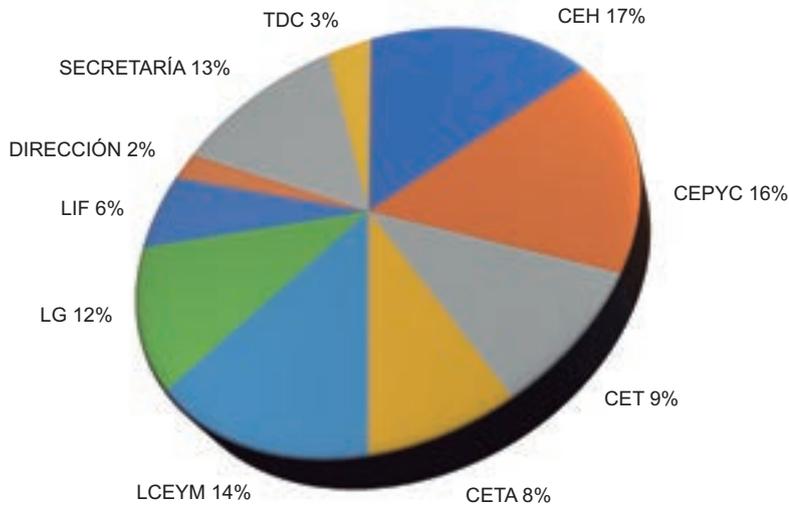


PERSONNEL BY CENTRE AND CATEGORY ON 31-12-2019

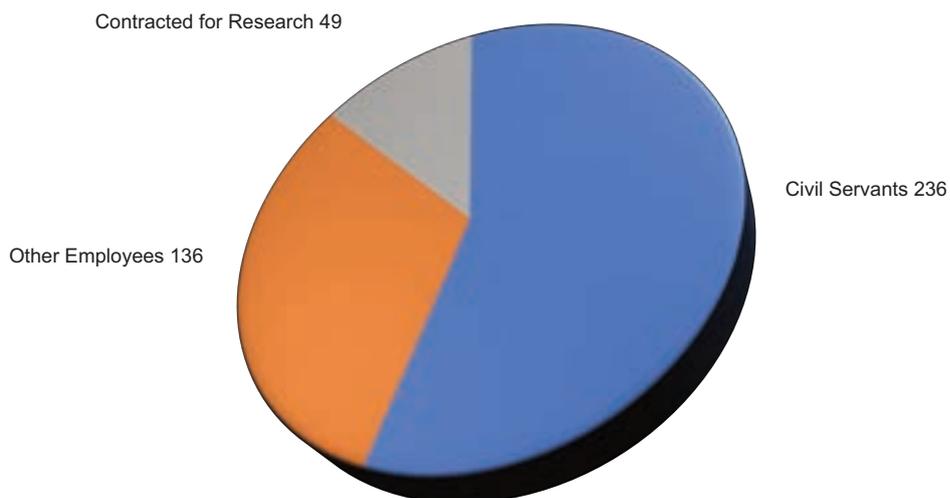
| | CEH | CEPYC | CET | CETA | LCEYM | LG | LIF | DIREC. | SECRE. | TDC | TOTAL |
|-------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|-----------|-----------|------------|
| Civil Servants | 41 | 39 | 18 | 15 | 27 | 24 | 17 | 6 | 37 | 12 | 236 |
| Other Employees | 22 | 20 | 13 | 10 | 29 | 19 | 4 | 2 | 15 | 2 | 136 |
| Contracted for Research | 9 | 9 | 6 | 8 | 4 | 8 | 4 | 1 | 0 | 0 | 49 |
| TOTAL | 72 | 68 | 37 | 33 | 60 | 51 | 25 | 9 | 52 | 14 | 421 |

CEH (Centre for Hydrographic Studies). CEPYC (Centre for Studies on Ports and Coasts). CET (Centre for Transport Research). CETA (Centre for Studies on Applied Techniques). LCEYM (Central Laboratory for Structures and Materials). LG (Geotechnical Laboratory). LIF (Railway Interoperability Laboratory). DIREC (Management). SECRE (Secretariat). TDC (Knowledge Transfer).

PERSONNEL BY CENTRE



PERSONNEL CATEGORY



MOST RELEVANT SELECTIVE PROCESSES CALLED IN 2019

Scale of Higher Expert Technicians from Autonomous Agencies

Posts offered for CEDEX:

- Autonomous Public Agencies of the Ministry for Transports, Mobility and Urban Agenda: free access: 7, internal promotion: 5
- Autonomous Public Agencies of the Ministry of Development and the Ministry for Ecological Transition and Demographic Challenge: No convocation in 2019

Corps of Civil Engineers

- For CEDEX: 3 posts have been requested by free access, and 1 by internal promotion

Corps of Technical Engineers for Public Works

- For CEDEX: 3 free access posts

Graduate staff hired for research projects

- Call for applications: 30 January 2019
- Places called for: 54
- Covered posts: 49

LABOUR RIGHTS AND POLICIES

Social dialogue and collective bargaining:

The Agency participates in the different negotiating bodies in the Ministry for Transports, Mobility and Urban Agenda (MITMA) for negotiation with trade union organizations (Departmental Board, Delegate Subcommittee of the Interpretation, Surveillance, Study and Application Committee (CIVEA), Social Action Commission, etc.).

Equality and integration plans

Article 51 of the Organic Law 3/2007, of 22 March, for effective equality between women and men, sets the performance criteria of public administrations, within the scope of their respective competences and in application of the principle of equality between women and men.

Equality policies

- Gender equality: The MITMA has its own Equality Plan that includes non-discrimination and the approach to gender violence with support measures for victims, which is followed by CEDEX given its nature
- Non-discrimination for other reasons: age, religion, race, country, sexual orientation, union membership, etc.
- Disability care

Reconciliation of work, personal and family life

By implementing rationalization measures:
Flexible, special or reduced working hours

Birth, adoption or foster leave

Leave for the parent other than the mother for birth, guardianship for adoption or foster care, and for the adoption of a child

Social action

The budget for Social Assistance in 2019 has amounted to € 63,400, not including the Retirement Awards or the costs of extracurricular activities for CEDEX employees' children.

The applications submitted have been 205, corresponding to 290 grants processed and materialized in 277 grants granted.

Of these, the most demanded have been:

- Studies for the children, € 36,550 to cover 157 grants
- Employee health treatments, with € 12,942 for 46 grants
- Transport, with € 13,926 for 47 grants

HEALTH, SAFETY AND HYGIENE AT WORK

Health promotion

Through initiatives, behaviour promotion programs, healthy practices implemented or maintained by the Agency such as:

- Winter road safety
- World Day on Occupational Health and Safety
- World Day without Tobacco
- Influenza vaccination campaign

Preventive activities

Performing medical examinations to all personnel and through the coordination of business activities related to the safety of external personnel in visit to CEDEX or our personnel in visit to other institutions.

Security

- Risk assessment
- Preventive planning, both in realization and in follow-up
- Participation in preventive training
- Accident investigation
- Assistance to safety committees and MITMA meetings
- Resolution of queries made by the centres and union delegates
- Emergency drills

TRAINING PLANS AND PROGRAMS

In the Area of Training, work has continued as in previous years with the aim of promoting knowledge transfer, thus managing activities in order to develop, on the one hand, the permanent training of their employees; and, on the other, to facilitate the transfer of technological knowledge among civil engineering professionals.



Training activities have been shaped through the continuous training, the Master's Degree in Soil Mechanics and Geotechnical Engineering, and the organization of numerous courses and conferences.

The facilities for internal promotion have materialized in a Continuous Training Plan, training time and social assistance.

QUALITY AND ENVIRONMENT MANAGEMENT

The Centre for Studies and Experimentation in Public Works (CEDEX) was accredited through the EN ISO 14001:2004 Standard between 2009 and 2017 in all its centres.

The accreditation of compliance with the requirements of EN ISO 14001:2015 has been renewed with the certificate number: ES09/6695. It's a multi-site certificate that includes all CEDEX centres. This certificate will be valid until 17 April 2021.

TRANSPARENCY AND GOOD GOVERNANCE

Specific measures that have been put in place to promote transparency or improve access to public information are:

- Implementation of the procedures associated with the entry into force of the Transparency Law
- Since 2013 contracts awarded are published on the Public Sector Contracting Platform (Order of the Minister of Public Works, of 27 June 2013)

- The MITMA is informed periodically, through scheduled questionnaires, about the activity carried out
- Answers are given to questions received through the Portal for the Management of Transparency Access Requests (GESAT), as well as the initiatives received through the Portal for Parliamentary Initiatives, both managed by MITMA

CODES OF CONDUCT

Specific ethical codes available to the Agency, following the protocols of the MITMA:

- Declaration of Principles in Occupational Risk Prevention (PRL)
- Declaration of Principles in Workplace Harassment in CEDEX (AL)
- Declaration of the Environmental Policy of CEDEX (GMA)
- Declaration of the CEDEX Quality Policy (Q)

The mechanisms to ensure their application are:

- PRL: PRL Management System comprised of the Own Prevention Service, the Health and Safety Committee and the set of PRL procedures
- AL: Workplace Harassment Protocol
- GMA: Environmental Management System implemented in CEDEX, according to ISO 14001
- Q: CEDEX Quality System in laboratories

COMMUNICATIONS MANAGEMENT

External communication

Main channels:

- www.cedex.es, e-mail, citizen information for the MITMA
- T- telephone support, library assistance, sale of publications, service to suppliers
- The Annual Report of Activities, the *Ingeniería Civil* journal, courses, conferences, meetings, and other training events

Internal communication

Main channels:

- CEDEX Informing, Intranet, e-mail and announcement boards
- The Annual Report of Activities, the *Ingeniería Civil* journal, and the *CEDEX Bibliographic Bulletin*
- Periodic meetings

ECONOMIC AND FINANCIAL RESOURCES

| EXECUTION OF THE 2019 REVENUE BUDGET | | | |
|--|-------------------|-------------------|-------------|
| SECTION | FINAL BUDGET | RECOGNIZED RIGHTS | EXECUTION % |
| 3. Fees, public prices and other incomes | 12,914,000 | 5,772,849 | 45% |
| 4. Current transfers | 15,301,900 | 15,340,488 | 100% |
| 5. Equity incomes | 1,550 | 555 | 36% |
| 7. Capital transfers | 990,000 | 794,887 | 80% |
| 8. Financial assets | 557,750 | 13,275 | 2% |
| TOTAL INCOME BUDGET | 29,765,200 | 21,922,054 | 74% |

| EXECUTION OF THE 2019 EXPENSE BUDGET | | | |
|--------------------------------------|-------------------|------------------------|-------------|
| SECTION | FINAL CREDIT | RECOGNIZED OBLIGATIONS | EXECUTION % |
| 1. Personnel expenses | 20,806,340 | 16,894,118 | 81% |
| 2. Goods and services | 5,504,740 | 3,698,550 | 67% |
| 4. Current transfers | 155,800 | 86,440 | 55% |
| 6. Investments | 3,260,000 | 2,864,029 | 88% |
| 8. Financial assets | 38,320 | 18,506 | 48% |
| TOTAL EXPENSE BUDGET | 29,765,200 | 23,561,643 | 79% |

| EQUITY AND LIABILITIES | 2019 | 2018 |
|---|-------------------|--------------------|
| EQUITY | 95,486,428 | 97,950,712 |
| Contributed equity | 84,251,752 | 84,251,752 |
| Generated equity | 11,190,289 | 13,654,573 |
| Profits or loss from previous years | 13,587,704 | 16,231,998 |
| Profit or loss for the year | -2,397,416 | -2,577,426 |
| Other capital increases pending imputation to income | 44,387 | 44,387 |
| CURRENT LIABILITIES | 3,168,655 | 2,342,839 |
| Current payables | 1,491,175 | 322,297 |
| Other receivables | 1,491,175 | 322,297 |
| Trade and other payables | 1,676,510 | 2,019,572 |
| Payables from management operations | 491,047 | 849,336 |
| Other payables | 818,136 | 763,990 |
| Public Administrations | 367,328 | 406,246 |
| Adjustments due to accrual | 970 | 970 |
| TOTAL EQUITY AND LIABILITIES | 98,655,083 | 100,293,551 |

SITUATION BALANCE SHEET

| ASSETS | 2019 | 2018 |
|--|-------------------|--------------------|
| NON-CURRENT ASSETS | 72,857,118 | 73,734,984 |
| Intangible fixed assets | 246,098 | 334,671 |
| Industrial and intellectual property | 1,950 | 0 |
| Computer applications | 244,148 | 334,671 |
| Tangible fixed assets | 72,603,264 | 73,392,264 |
| Lands | 28,515,852 | 28,515,852 |
| Constructions | 32,298,200 | 33,175,179 |
| Other tangible fixed assets | 10,993,461 | 11,691,200 |
| Fixed assets in progress and prepayments | 795,752 | 10,033 |
| Long-term financial investments | 7,755 | 8,049 |
| Credit and Debt securities | 7,166 | 7,460 |
| Other financial investments | 589 | 589 |
| CURRENT ASSETS | 25,797,966 | 26,558,568 |
| Trade and other receivables | 21,916,951 | 22,357,602 |
| Receivables from management operations | 18,927,392 | 19,792,581 |
| Other receivables | 233,668 | 366,643 |
| Receivable from public authorities | 2,755,891 | 2,198,378 |
| Long-term financial investments | 9,174 | 3,649 |
| Credit and Debt securities | 9,174 | 3,649 |
| Adjustments due to accrual | 289 | 289 |
| Cash and cash equivalents | 3,871,551 | 4,197,027 |
| Cash | 3,871,551 | 4,197,027 |
| TOTAL ASSETS | 98,655,083 | 100,293,551 |





**OUTSTANDING
FACILITIES**

Full-Scale Accelerated Pavement Test Track



Contact: rafael.rodriguez@cedex.es / laura.parra@cedex.es

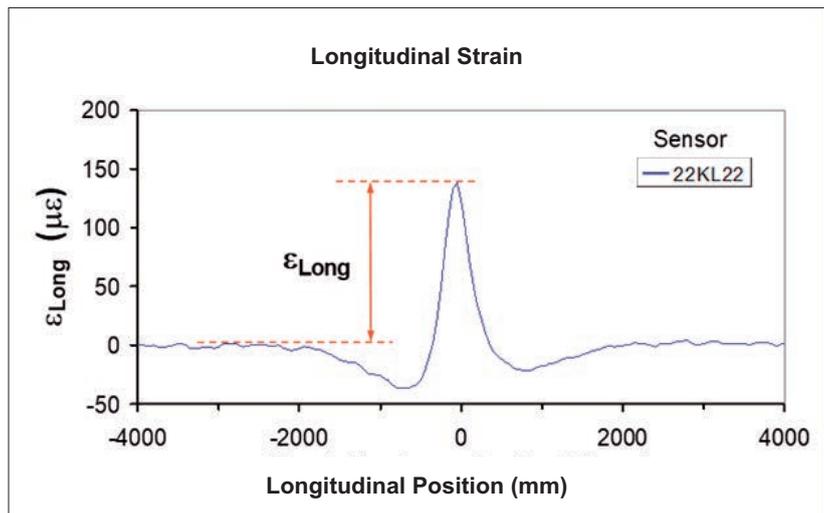
Full-scale pavement accelerated test track of the Centre for Transport Research (CTR/CET) of CEDEX is the reference facility to emulate –in an accelerated way– the effects of traffic loads on the structure of real road pavement sections.



General view of the full-scale accelerated pavement test track.

MAIN FEATURES

- Application of repeated and controlled loads by means of 2 vehicles that emulate real traffic. The vehicles have conventional tires and suspension
- 2 straight sections of 75 m joined by two curved sections with a radius of 25 m
- Speed between 0 and 60 km/h
- Applied load of a semi-axle of 6.5 t (variable between 5.5 and 7.5 t)
- Conventional twin or single wheel
- Automatic in motion transversal position change system (14 positions; possible width 1.0 - 1.4 m)



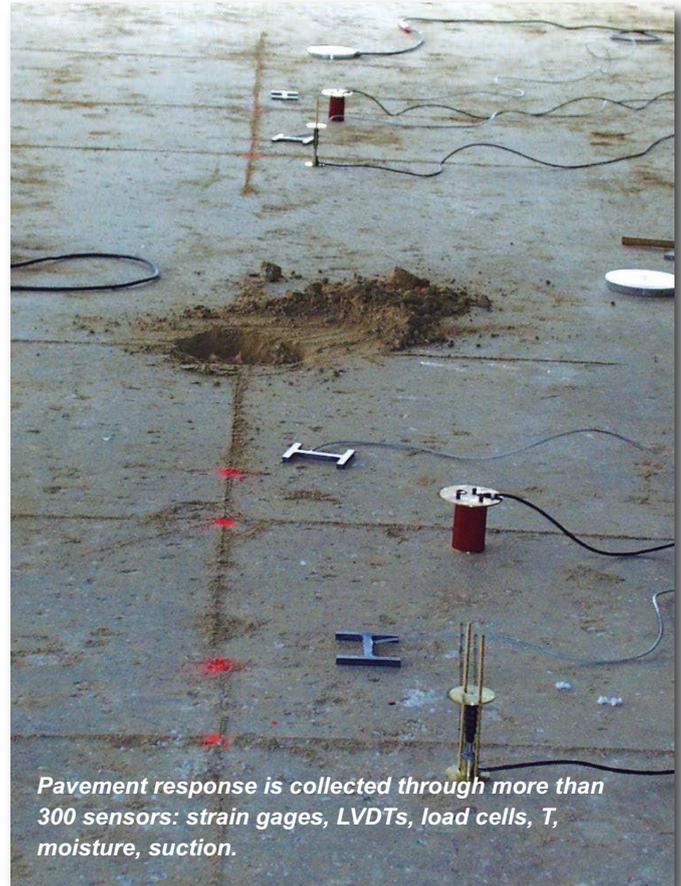
During each test, more than 3 million curves are recorded, analyzed and stored in a database.



APPLICATIONS

- Evaluation of the structural response under a damage accumulation process
- Development and validation of road pavement design mathematical models
- Surface characteristics analysis of new bituminous mixtures for surface course layers
- Paint quality tests

To ensure a better service, work is being done on the update of the facility. Technical requirements for increasing its testing capacity have already been defined; improvements related to the duplication of load axles, the increase in maintained speed and the possibility of varying the damping parameters to simulate specific traffic characteristics can be highlighted.



Pavement response is collected through more than 300 sensors: strain gages, LVDTs, load cells, T, moisture, suction.



Accelerated test tracks are ideal for testing new materials and new construction solutions before they're implemented in real road sections.

Leaching Test Laboratory of the Centre for Transport Research



Contact: julio.termenon@cedex.es

This laboratory focuses on the environmental characterization of the materials to be used, both in the construction of road pavements and in other applications, such as recycled aggregates and wastes. This work is carried out by studying the leaching behavior of these materials, using specific standardized tests, so that the main leaching mechanisms can be defined, and subsequently analyzing the eluates obtained using appropriate instrumental techniques in order to assess the release of dangerous substances that could cause an environmental impact.

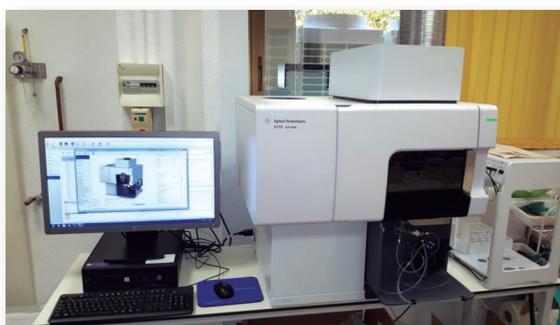
Leaching behavior tests



Leaching behavior test by upflow percolation (column), controlled by software and configured with the parameters of the standards UNE-EN 14405 and NPR-CEN-TS 16637-3.

Conformity test for batch leaching (tumbling), according to standards:

- UNE-EN 12457-1
- UNE-EN 12457-2
- UNE-EN 12457-3
- UNE-EN 12457-4



Eulates Analysis. Metal Content

Determination of metal content through optical emission spectroscopy by inductively coupled plasma (ICP-OES). Agilent 5110 ICP-OES equipment with Dual View technology (axial and radial), low argon consumption, very short analysis time and automatic measurement (up to 250 samples) thanks to its Autosampler SPS 4.

Eurobalise Laboratory

Contact: susana.herranz@cedex.es



The Eurobalise Laboratory of the Railway Interoperability Laboratory (RIL/LIF) of CEDEX has been the first European laboratory accredited for the execution of the Eurobalises and Antennas Certification tests of ERTMS.



As a result of the first European railway interoperability demonstration project (EMSET Project) coordinated by CEDEX, the first European Eurobalise laboratory, accredited in 2005 by the National Accreditation Entity (ENAC), was created for the execution of the Eurobalise and Antenna/BTM tests, according to the European standard described in Subset-085, of the Technical Interoperability Specification on the Control, Command and Signalling subsystem.

This laboratory, which has been the European laboratory of reference for years, has tested equipment from almost twenty suppliers worldwide and is accredited and/or qualified to carry out the following tests:

'Test Specifications for Eurobalise FFFIS':
Eurobalise and Antenna/BTM tests.
Subset-085

Subset-103 'Test Specification for Euroloop'

Subset-116 'Eurobalise Onboard Equipment, Susceptibility Test Specification'

The laboratory also participates in special studies such as the feasibility of Eurobalises for three-lane roads, and takes part in several European projects using the Galileo satellite system for the implementation of **virtual balises** on ERTMS lines.



Above. Eurobalise Laboratory.

Centre. Test instrumentation.

Below. Calibration test.



ERTMS Traffic Simulation Laboratory

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The functional tests of ERTMS are carried out through the exchange of information, the exchange of information between track and train, being identical to what happens in a real environment. In using this tool, the complete purification of the entire system is achieved before its deployment on the real line, thus saving time and money.



Traffic Simulation Lab.



Barcelona Commuter Trains.



Routes setting.

The ERTMS (European Rail Traffic Management System) Traffic Simulation Laboratory of the Railway Interoperability Laboratory (RIL/LIF) of CEDEX, has been the first European laboratory to carry out out tests of real ERTMS N1 and N2 lines in the laboratory.

In order to support ADIF and RENFE OPERADORA in the process of commissioning new lines and trains equipped with ERTMS, the Traffic Simulation Laboratory provides the possibility to test the functionality, and interoperability of the line through the execution of the necessary set of tests for commissioning it.

This is achieved by introducing in the laboratory the ERTMS track components Balise Telegrams in N1 and RBC (Radio Block Center) in N2, and the connection thereof to the Traffic Simulator that simulates the topology of tracks, detours, track circuits and signals of the line.

In parallel, the onboard ERTMS or EVC (European Vital Computer) equipment is integrated and connected to the train movement simulator of the laboratory. The Traffic Simulation Laboratory has refined the main Spanish lines equipped with ERTMS (Madrid-Valencia, Valladolid-Burgos-León, Olmedo-Zamora, Cercanías Madrid, Cercanías Barcelona, etc.), as well as lines from other countries (Saudi Arabia, Belgium or Senegal).

Eurocab Laboratory

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The Eurocab Laboratory of the Railway Interoperability Laboratory (RIL/LIF) of CEDEX has been the first European laboratory to carry out the execution of certification tests of ERTMS onboard equipment or EVC. In 2019 this lab has certified the ERTMS On Board Units that will circulate throughout France's high-speed network.



DMI with a robot.

*Balise message
at Eurocab lab.*



Eurocab lab.

As a result of the EMSET project, and initially using the simulators developed in that project, CEDEX created the Eurocab Laboratory, which in the years 2004-2005 carried out the first European campaign to test the interoperability of onboard ERTMS or EVC equipment (European Vital Computer) of all European manufacturers.

Since 2005, CEDEX leads the European group responsible for drafting the ERTMS Test Specification (Subset-076) containing the set of tests to which this equipment must be submitted to demonstrate compliance with the System Requirements Specifications (Subset-026), of the Technical Interoperability Specification on the ERTMS Control, Command and Signalling subsystem.

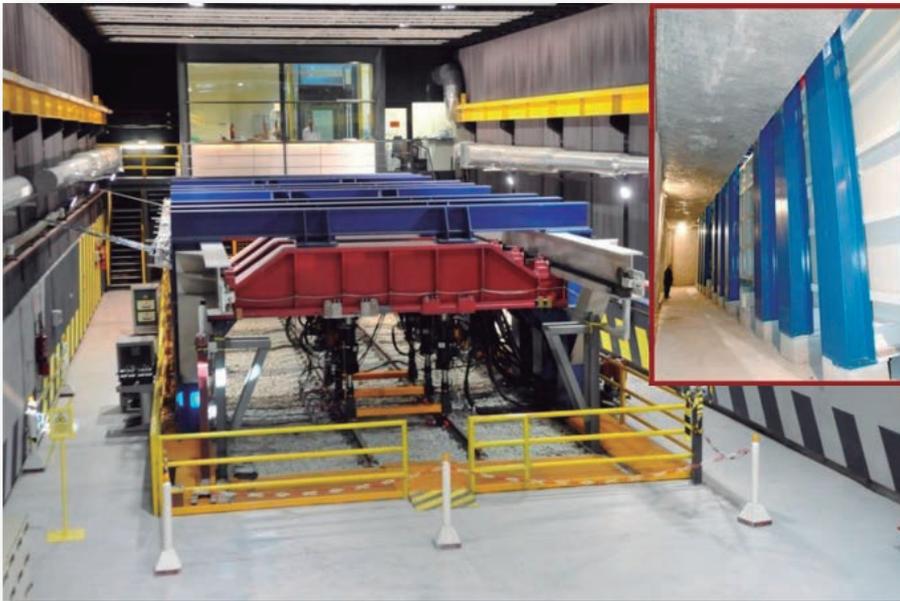
All European ERTMS manufacturers have passed through the Eurocab lab: Alstom, Ansaldo, Bombardier, CAF, Hitachi and Siemens, so the laboratory has become the European benchmark, accredited by ENAC according to standard 17025 in 2010

CEDEX Track Box (CTB)

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CEDEX Track Box (CFC) is a 21 m long, 5 m wide and 4 m deep facility whose main objective is to test, at 1:1 scale, complete railway track sections of conventional and high-speed lines for passenger and freight trains, at speeds of up to 420 km/h.



General view of the test facility.

| Actuator Characteristics | | |
|--------------------------|-------------------|----------------------------|
| Type of Actuator | Servo-hydraulic | Piezoelectric |
| Simulation | Passing-by trains | wheel & track imperfection |
| Max. Load. | 250 kN | 20 kN |
| Frequency | 50 Hz | 300 Hz |



Detail of sensors in the railway track.

This unique facility in the world allows, in just one week of laboratory work, to determine the effect that annual train traffic has on a real railway track section. The reproduction of the effect of the approaching, passing-by and departing of a train in a test cross-section, as it occurs in a real track section, is performed by application of loads, adequately unphased as a function of the velocity of the train which is being simulated, is accomplished by three pairs of servo-hydraulic actuators. Passenger and freight trains can be simulated at speeds of up to 420 km/h.

The railway track response, in terms of displacements, velocities, accelerations and pressures, is collected from approximately 150 linear variable differential transformers (LVDTs), geophones, accelerometers, and pressure cells installed inside both the embankment and the bed layers (ballast, sub-ballast and form layer) of the track.

Types of tests to be performed

- Simulate the pass-by of trains at speeds of up to 420 km/h
- Ballasted or slab tracks
- Static or fatigue tests with millions of axle trains
- Lateral and longitudinal track resistance

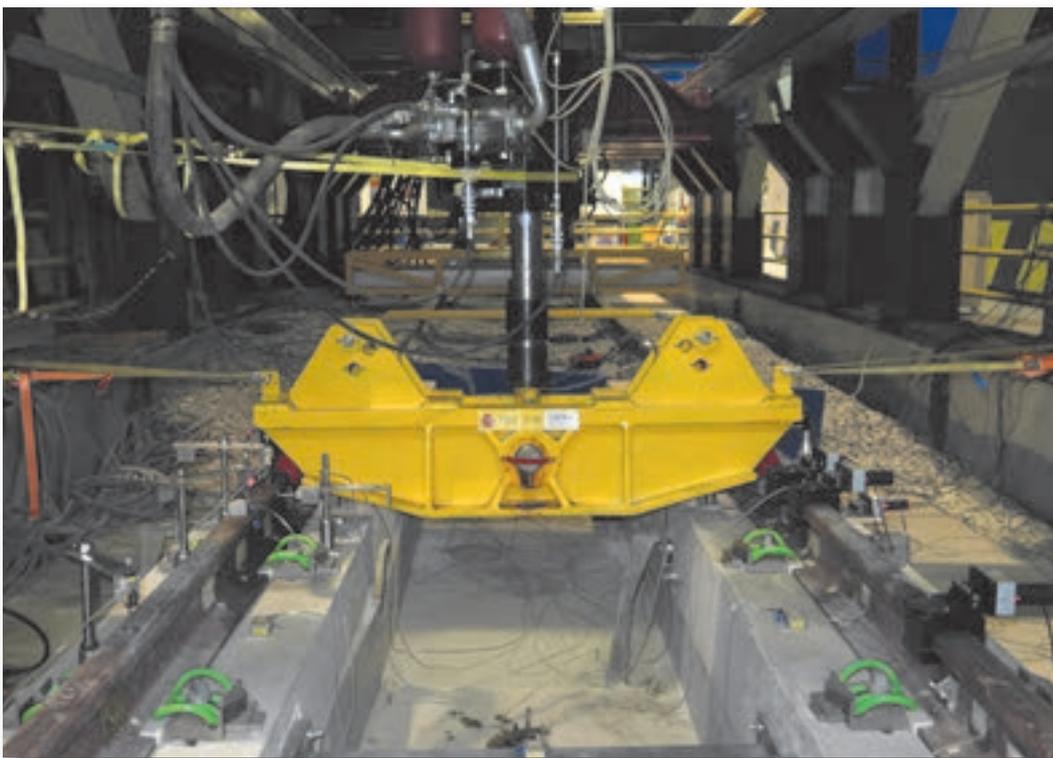
Data acquisition system allows collecting information, in real time, from more than 150 channels simultaneously.

Since its inauguration in 2004, the most important works that have been carried out at the CEDEX Track Box, within European projects, have been:

- Determination of fatigue curve of ballast and sub-ballast material
It allows to modify the maintenance of the ballast layer
- Analysis of the optimum thickness of bituminous sub-ballast
The bituminous sub-ballast layer was reduced from 20 to 8 cm
- Study of the propagation of vibration through the trackbed and embankment
It guarantees using under sleeper pad to avoid vibrations
- Study of the effect of fouling with sand on the behaviour of the ballast layer
It allows to analyze the behaviour of ballast layer fouled by sand
- Homologation tests of prototypes of the slab
Detection of issues in tested prototypes
- Study of the effects of very high speed (of up to 400 km/h) on the mechanical behaviour of track beds
Enhancing the design of future projects for high-speed lines to 400 km/h



Railway administrations and enterprises related to CEDEX Track Box works.



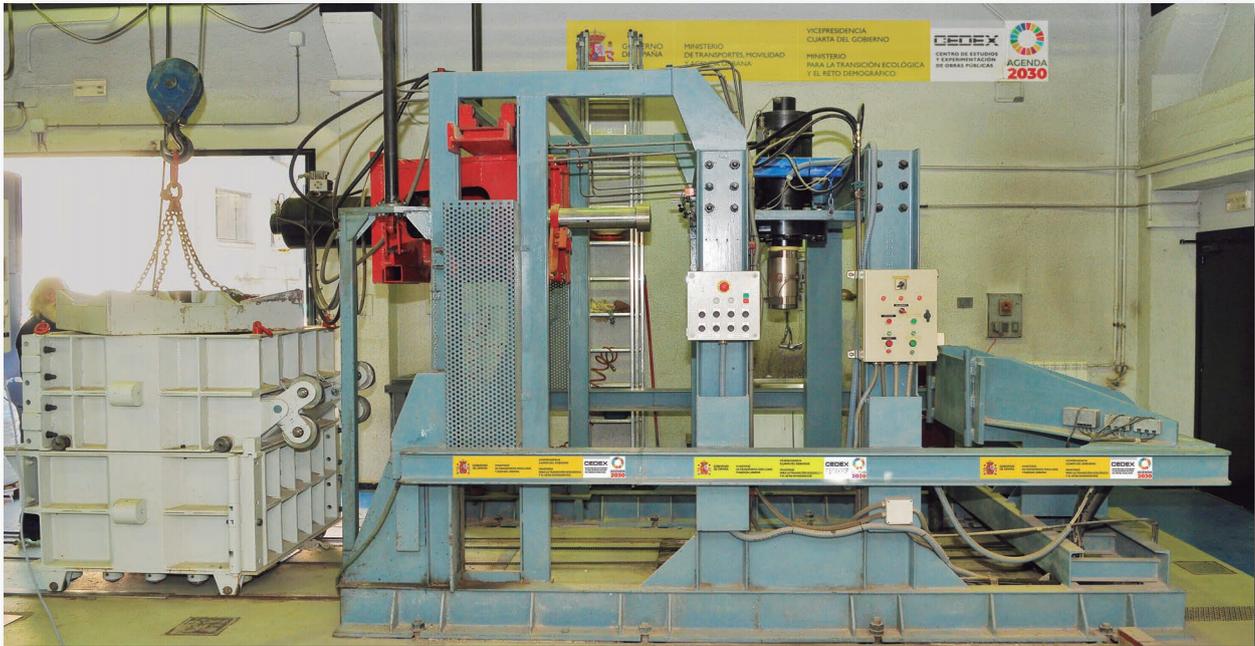
Fatigue test on slab track.

Direct Shear Box for Coarse Granular Materials

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The Direct Shear Box for Coarse Granular Materials is located at CEDEX Geotechnical Laboratory. This device has a shear plane of 1 m x 1 m and a maximum specimen height of 1.2 m. These dimensions allow for the testing of coarse granular material (of up to 200 mm of maximum particle diameter, depending on the standard used).



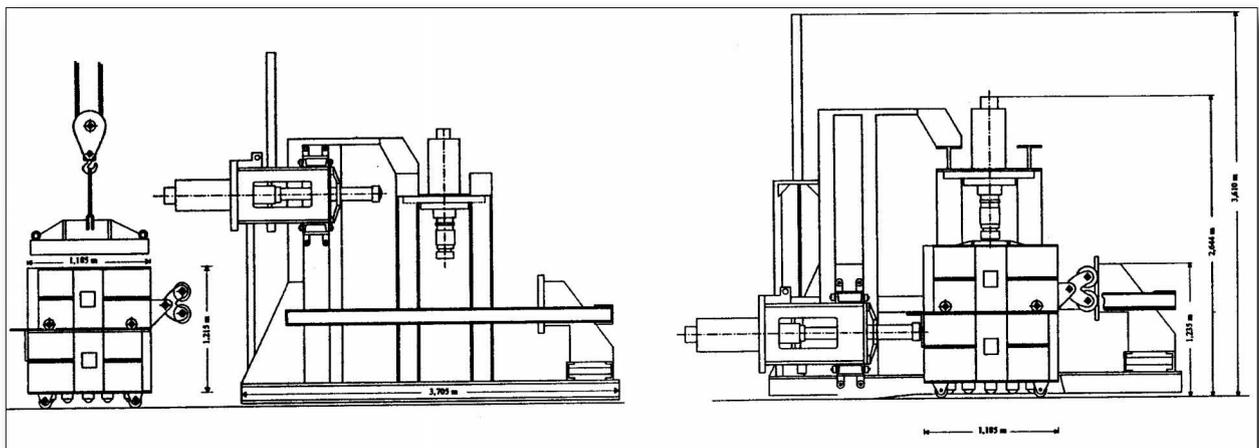
Lateral view of the Large Shear Box at CEDEX Geotechnical Laboratory.

This equipment has been widely employed for the study of rockfills for ports and dams, as well as of rail ballast and other coarse granular materials. The shear strength of the contact between soils and concrete structures or soils and geotextiles has also been studied.

This facility is unique in Spain and only a reduced number of shear boxes of these dimensions are available in the world.

Main specifications

- Direct shear box side: 1000 mm
- Direct shear box height: 1200 mm
- Maximum shear load: 1000 kN
- Maximum vertical load: 1000 kN



Different performed tests

Direct shear tests of granular soils

Direct shear tests in the soil-structure contact (soil-concrete structure, ballast-sleeper, soil-geotextile, etc.)

Pull out tests for geosynthetics

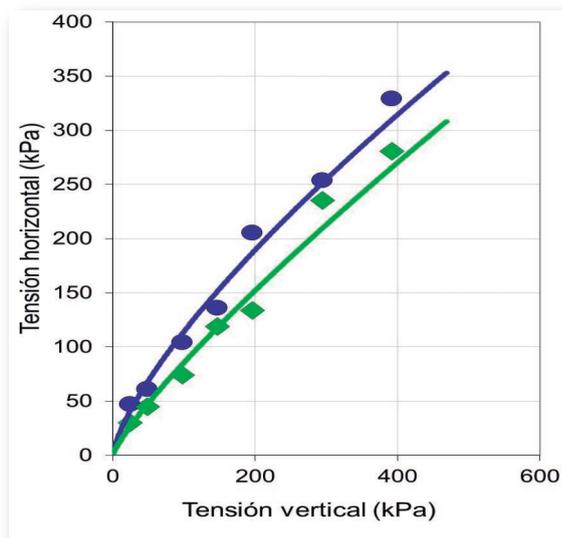
Both normal and shear load are applied by two servo-controlled hydraulic pistons with a load capacity of 1 MN each.

Both the control of the load and shear rate, as well as the data collection, are made by using an automated multichannel controlling system.

The sample is placed in the shear-box by vertical discharge. Some compaction can be made by using the vertical actuator or a small jackhammer compactor.

Some relevant projects where this equipment was used:

- Study of El Prat pier at Barcelona harbour.
- Study of Huelva harbour breakwaters.
- Study of the deformability of coarse soils for Yesa dam.
- Study of the shear strength ELT (End-of-Life Tyres) for its use in embankments.
- Study of the Sleeper-Ballas shear strength.



Seismic Simulator with Six Degrees of Freedom



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Tests performed: seismic structural, modal analysis for determination frequency, frequency sweep, and random signal for fatigue of railway material.



Vibration and shock test on a converter equipment.



Seismic test. ANSTER project.

Within the field of seismic engineering, it's of fundamental importance to carry out experimental studies of the behaviour of structural elements or models.

The seismic simulator with six degrees of freedom, the only facility in Spain with these features, installed in the Central Laboratory for Structures and Materials (LCEYM) of CEDEX, allows the application on a 3 x 3 m steel platform, over which the element to be tested is installed, an action consisting of a spatial movement defined in function of time by its six linear and angular components.

The movement is obtained by means of four hydraulic vertical actuators and another four horizontal. All the system is servo-controlled and optimized to ensure that the difference between the movement components to be applied and those really obtained is minimal.

The seismic excitation applied to the simulator can be defined from an external file or be numerically synthesized from a compatible response spectrum, or by laws of amplitude and preset phases. Among other tests, it should be noted: the radar antenna for the Juan Carlos I aircraft carrier (INDRA-Ministry of Defense); seismic tests for the Earthquake Safe Nuclear Storage (ANSTER) project; collaborations with universities and foundations for seismic tests; tests for the National Seismic Network; Civil Protection; and vibration and crash tests of railway equipment.

Dimensions: 3 x 3 m

Degrees of freedom: 6

Actuators:

- 4 vertical of 147 kN
- 4 horizontal of 147 kN

Maximum model mass: 10 t

Maximum frequency: 60 Hz

Maximum vertical displacement:
±50 mm

Maximum horizontal displacement:
±100 mm

CEDEX-Drone Operator

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CEDEX Drone Operator has been enabled to fly drones for video and photography, topography survey and structure inspections.

CEDEX has developed the strategy for using drones to support field works. The way to get that purpose has been to create a Drone Operator team within its own staff. This Drone Operator, coordinated by the Central Laboratory for Structures and Materials, can provide help to all the different areas of CEDEX: infrastructures inspection, rock mass characterization, slope movement analysis, erosion and coastal dynamics, vegetation and underground watercourses analysis with multispectral images, stream velocity estimation, etc.

All CEDEX centres and laboratories have an agent in the Drone Operator staff, and at least one drone pilot. In this way, resources and investments of CEDEX have been optimized and coordinated.

At present, CEDEX has two drone aircrafts: one for general purpose, of small size and very handy; and another bigger and capable of carrying light loads such as those of the different sensors that some operations may well require. CEDEX Drone Operator is enabled to record video and take photographs, topography survey, and structure inspections.

Flight operations are complemented with photogrammetric survey restitution and image analysis. These techniques ease field data acquisition and supplement means of access for structure inspections, like the road bridge inspection platform. The next step for the Drone Operator will be to upgrade flight abilities and available devices in order to improve our scope of action.



MATRICE 600 PRO. Hexacopter

Double onshore control station

Micro 4/3 Zenmuse X5 camera
(Zoom with equivalent focal length
28-84 mm)

Flight time: 38 minutes
approximately

Max. Takeoff Weight
Recommended: 15.5 kg

Payload: 5.5 kg



Structural inspection of a railway bridge.



PHANTOM 4. Cuadricopter

Weight (batteries and propellers
included): 1.380 kg

Max. Flight time: 28 minutes
approximately

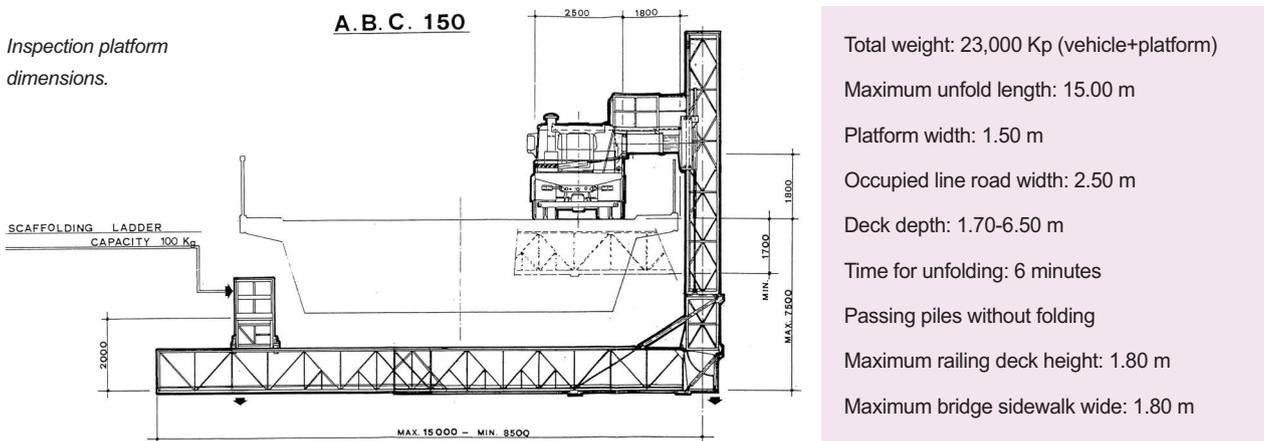
Vision-based positioning system



Road Bridge Inspection Platform

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The maintenance of road bridges, as structural country heritage, is increasing its importance because of the high level of the Spanish infrastructure development. In fact, infrastructure conservation is aligned with the 12th of the United Nations Sustainable Development Goals (Ensure sustainable consumption and production patterns), and with the aim of getting a sustainable industry within the European Green Deal.



As a part of **maintenance works, structural inspection and monitoring** have a special relevance. In bridges inspection cases, these works demand to get to the underside of the deck, where most damages are concentrated. This kind of works requires a system:

- Safe enough for inspection teams
- Fast enough to focus time on inspection but not on access
- Minimum interruption time of road use
- Flexibility to adapt to different structural types and dimensions

For this purpose, the Central Laboratory for Structures and Materials of CEDEX has a road bridge inspection platform that complies with the indicated requirements.

The platform, which is fixed on a truck, consists of some metallic modules that are moved by a hydraulic circuit. The system allows rapid unfolding when the truck arrives at the bridge. When the platform is under or at the side of the deck, a five-member inspection team can inspect it. The platform can move up and down, turn, and adapt its length, under the deck. All movements are controlled from the platform itself as the truck moves slowly.



Inspection of the A8 bridge over Agüera estuary.

Microscopy Laboratory

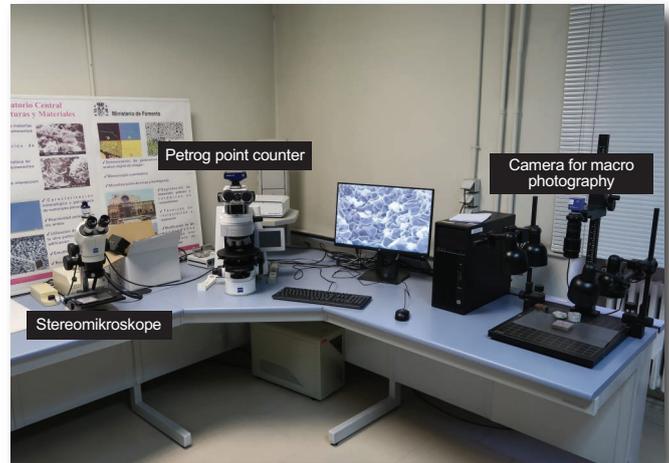
Contacts: alberto.velasco@cedex.es / pilar.alaejos@cedex.es



The Microscopy Laboratory has a scanning electron microscope, with energy dispersive X ray spectroscopy (EDX). This unit is used to identify and measure the abundance of elements and map their distribution, in any kind of solid sample. The microscope has a secondary electron detector, energy-dispersive X-ray spectroscopy and Peltier stage, which offers the possibility to crystallize different compounds, varying the humidity of the sample.



Scanning electron microscope.



General view of the light microscopy section.

Recently, the microscopy system has been renewed with a light microscope fitted with a circular rotation stage, equipped with a semi-automatic Petrog counter and a motorized stage.

This equipment, installed at the Central Laboratory for Structures and Materials, allows the analysis of aggregates used in concrete and the **quantification of reactive components** within them, in two steps: light microscopy analysis and evaluation in the scanning electron microscope. This technique is applied to study concrete affected by expansive reactions, as sulfate attack or alkali silica reaction.

The laboratory has also a stereo microscope, recently improved by coupling a camera for the macroscopic study of materials.

This new equipment allows **the analysis of damaged concrete** from the visu to micron sizes. So, it covers all the optical levels of the sample.

In addition to the study of pathologies in concrete, this laboratory analyzes other materials, such as geomembrane and steel, making this equipment essential in the optical study of all construction materials.

Scanning electron microscope:

- Magnification range: 5 to 1 000 000x
- Resolution 3.0nm with 30kV
- Detectors: secondary, Energy – dispersive X-ray spectroscopy, Cathodoluminescence and Peltier Stage

Light microscope:

- Magnification: 12.5x, 25x, 50x, 100x, 200x y 500x
- Maximum resolution 0.25 microns
- Petrog counter

Laboratory of Isotope Applications



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http://www.cedex.es/CEDEX/LANG_CASTELLANO/ORGANISMO/CENTYLAB/CETA/LINEAS/07_REVIP.htm

The Area of Isotope Applications of CEDEX provides technical support to the Directorate-General for Water (DGA), of the Ministry for Ecological Transition and Demographic Challenge, for compliance with European Union Directives in the framework of water management, as well as to the Nuclear Safety Council (CSN) for compliance with the EURATOM Treaty in the framework of radioactivity surveillance of the aquatic environment. Since 2012 the laboratory is accredited by the National Accreditation Entity (ENAC), under the Norm UNE-EN ISO/IEC 17025, N° 82/LE1955.



General view of the Chemistry Laboratory.

A chemistry laboratory is available, for water sample preparation in compliance with the technical instructions for analysis.

The Laboratory of Isotope Applications has set up a group of detectors with electronic chains of great stability and reliable calculation methods for the application of the following analytical techniques:

1. ZnS(Ag) solid scintillation counting, for the measurement of gross alpha activity.
2. Gas-flow proportional counting, for the measurement of gross beta activity.
3. Atomic absorption spectrometry, for the measurement of potassium concentration and subsequent calculation of the residual beta activity.
4. High Purity Germanium (HPGe) Radiation Detection, for gamma spectrometry and the measurement of the activity of cesium-137 and cesium-134.

Activities in radiological quality of water

- Analysis of surficial inland, marine and drinking water
- Reference radiological background
- Environmental monitoring networks
- Norms for quality assurance of environmental radiological analysis

Activities in environmental isotope hydrology

- Characterization of the hydrologic cycle
- Evaluation of conceptual models in hydrology
- Dating and evaluation of residence time to assess the renewal capacity of water bodies



Detail of the Laboratory.

5. Liquid scintillation spectrometry, for the measurement of the activity of tritium through direct and electrolytic concentration methods.
6. Ionization chamber, for the continuous measurement of radon-222 in air and water.

A combination of methodologies is also used in the laboratory for the determination of the isotopic relationships of light elements that includes laser spectrometry for deuterium and oxygen-18 in water, mass spectrometry for deuterium and oxygen-18 in water, and carbon-13 in dissolved inorganic carbon (CID). These methods are applied to trace water provenance and solute transport processes of interest in hydrology and geochemistry. Dating techniques are used by measuring tritium activity in water through liquid scintillation counting after electrolyte concentration, and geochemical models for carbon-14 dating of the Dissolved Inorganic Carbon, in order to estimate the times for the renewal of water resources and the transport of contaminants in groundwater bodies.

Spanish Network for Isotopes in Precipitation (REVIP)

Managed by CEDEX since 2000 in collaboration with the State Meteorological Agency (AEMET), this Network provides reference information which is applied in studies of isotopic hydrology in Spain, being increasingly used in the calibration of general circulation models of the atmosphere, studies of climate change and ecosystems functioning, and food security



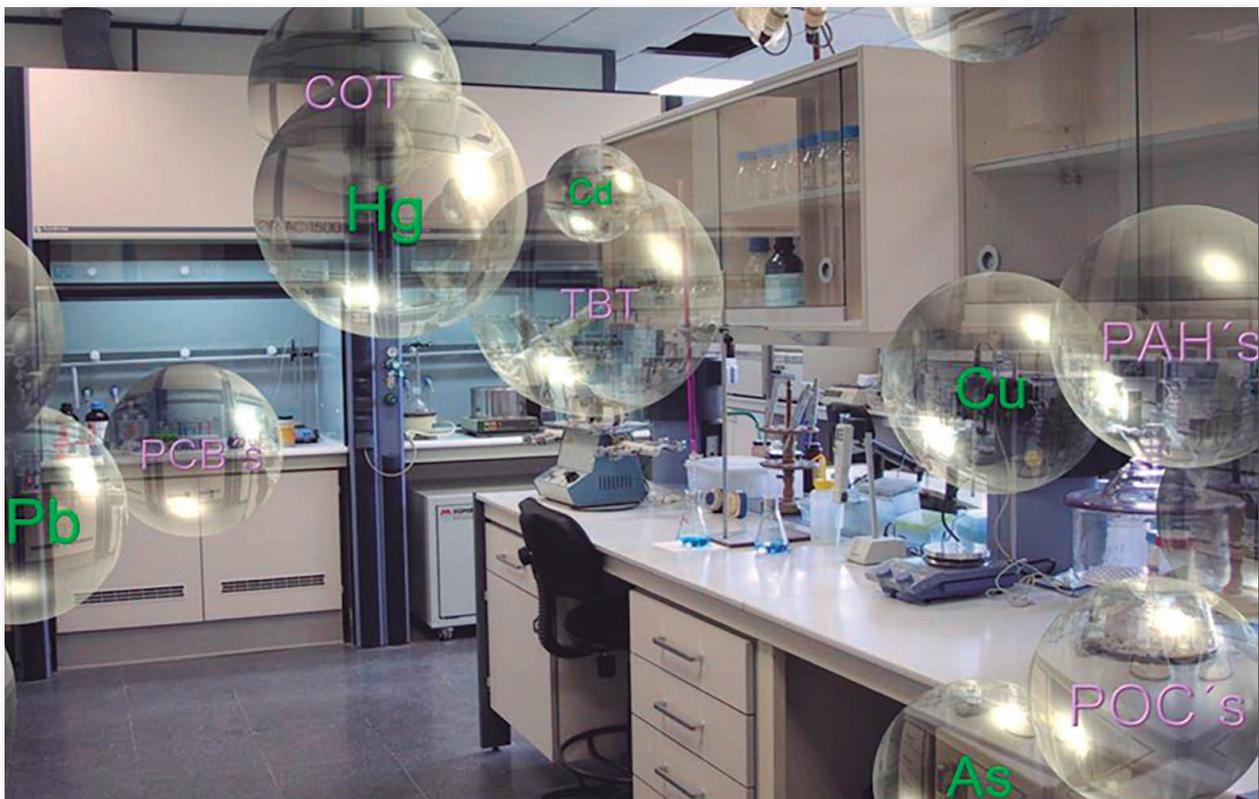
Planchettes for measuring radiological indices in continental (left) and marine (right) water.

Marine Environment Quality Laboratory

Contact: ricardo.obispo@cedex.es

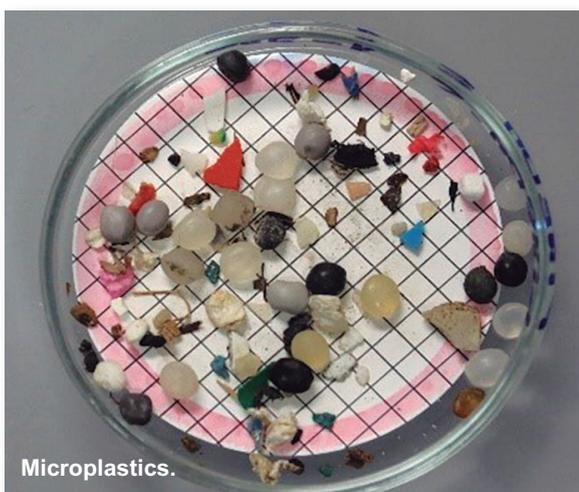


This laboratory is highly specialized in specific skills in coastal environment and maritime ports, providing the analytical support for carrying out the main lines of work developed by the Marine Environmental Department of the Centre for Studies on Ports and Coasts, with a permanent evolution depending on the needs of this department.



Marine environment quality laboratory.

The laboratory is divided into several sub-laboratories: general laboratory, spectroscopy, chromatography, microbiology and ecotoxicological laboratory, being equipped with the instrumentation required to carry out the analytical determinations in different matrices such as seawater, marine sediments and biological samples.

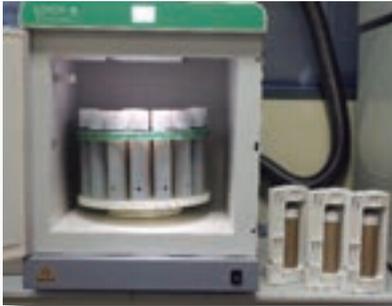


Microplastics.

Main Activities

- Development of technical annexes and analytical methodologies for environmental regulation
- Environmental monitoring of works in coastal areas
- Monitoring of microplastic pollution
- Sand quality for beach nourishment
- Dredged material characterization
- Studies on discharges from desalination plants
- Hydrocarbons pollution. Oil spill identification
- Development of testing procedures for oil spill response products on the sea

GENERAL LABORATORY



- RECEPTION, PRESERVATION AND FRAGMENTATION OF SAMPLES
Drying, homogenization, milling, etc.
- PRELIMINARY TREATMENTS
Acid digestions and organic extractions, etc.
- MICROPLASTICS IDENTIFICATION
- GENERAL PARAMETERS
Conductivity
Salinity
Density
Grain size
Turbidity
Suspended solids, etc.

SPECTROSCOPY LABORATORY



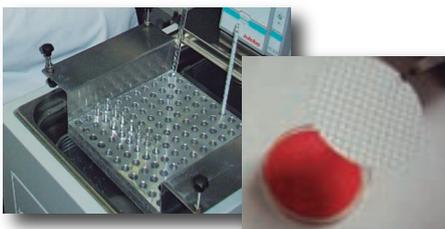
- ATOMIC ABSORPTION SPECTROMETRY:
Hg, Cd, Pb, Cu, Zn, Ni, Cr, As, Al, etc.
- ATOMIC FLUORESCENCE: Hg (ppt)
- SPECTROMETRY UV/VIS: nutrient
- TOTAL ORGANIC CARBON (TOC)

CHROMATOGRAPHY LABORATORY



- GAS CHROMATOGRAPHY /MS/MS
- GAS CHROMATOGRAPHY/FID
- GAS CHROMATOGRAPHY /ECD
- PCBs, PAHs, Hydrocarbons, organotin compounds (TBT)

LABORATORY OF MICROBIOLOGY



- MICROBIOLOGICAL POLLUTION
Faecal coliforms, Enterococci, Fungi, etc.
- ECOTOXICITY
Bioluminescent test *V. fischeri*
(Microtox), Bioassays, etc.

Ship Maneuvering Simulator of CEDEX

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The ship maneuvering simulator is a unique installation that reproduces in real time the dynamic behavior of a ship subjected to the action of wind, waves and currents, and it's piloted by nautical personnel.



Overview of the main bridge of the CEDEX simulator.

This simulation system complies with the different requirements of the STCW95 convention and holds the Det Norske Veritas A (NAV) classification, being able to fully simulate any bridge operation, including the ability to reproduce the most advanced maneuvers in restricted waters.

The system consists of a main full mission category navigation bridge, a secondary bridge, and 4 simulation stations implemented on as many workstations. Its main technical characteristics are:

Main Bridge

Provided with:

- Steering and control elements: rudder, machine command telegraph, control of thrusters and anchors, navigation aids: GPS, radar, VHF, internal communication, and voice signals.
- Data: tachometer, rudder angle, heading indicator, doppler log, ship speed, depth sounder, etc. Computer generated synthetic radar image with ARPA radar capabilities.
- High resolution panoramic exterior image: 9 channels, cylindrical surround screen with 270° horizontal amplitude, and 7.5 m radius.
- Projection system consisting of 9 high resolution CRT projectors.
- Point of view control: view from the bridge, from the ailerons, looking aft, a "bird's eye view", and binocular (configured on one of the channels).

Secondary Bridge

Provided with:

- Maneuvering console for ships with ASD and conventional propulsion, propulsion and steering control, rope and mooring control, thruster control, VHF communication, and ARPA radar screen.
- Maneuvering console for a Voith-Schneider powered tug.
- Panoramic and high resolution exterior image: 3 flat screens of 120° aft, a "bird's eye view", and binocular (configured on one of the channels).
- Total horizontal width, 3 LCD projectors of 40° horizontal width.
- Point of view control: view from the bridge, from the ailerons, looking aft and from a "bird's eye view".
- Instrumentation screen: conventional and azimuth telegraph, rudder control, GPS, etc.



View of the secondary bridge.

Four Auxiliary Bridges

- Microsimulators equipped with: digital instrumentation, conventional and azimuth telegraph, rudder control, GPS, VHF communication and plasma screen (42 ") shared by the four stations for bird's-eye view.

All these bridges are capable of operating in a synchronized way (for example, a pilot manages the main ship and others the tugboats that are assisting him, in the same navigation environment), or independently attending to different studies simultaneously.

- ▶ Simulation Control Station, to:
 - Planning the maneuvers, by configuring the weather conditions (waves, tide, wind and current) and the visibility parameters (fog, rain, snow, night and day).
 - Implementation of the numerical model of ships.
 - Implementation of the scenario of the maneuvers.
- ▶ Computer applications to generate numerical models and visual models of the ships and visual 3D, 2D and radar models of navigation environments.
- ▶ "AMBAR" computer application for analysis of each individual maneuver or a group of maneuvers carried out under homogeneous conditions applying statistical methods.

This facility has replaced another simulator put into operation at CEDEX in 1992. Since its installation at the Centre for Studies on Ports and Coasts in 2002, ship maneuvering studies have been carried out in almost all the

Types of feasible studies

- Port access and exit maneuvers and ship docking
- General navigation
- Dynamic analysis of the behavior of anchored vessels
- Analysis of maritime incidents and accidents.
- Towing ships that need assistance and floating structures, such as wind turbines

ports of the Spanish Port System, the most significant being the following:

- ▶ Design of new port developments: outer ports of Ferrol, Coruña, Gijón, etc.
- ▶ Expansion or change of uses of its facilities: ports of Tarifa, Motril, Alicante, Castellón, Barcelona, Mahón, Las Palmas, etc.; and some abroad: Buenaventura and Cartagena de Indias (Colombia).
- ▶ Analysis of the behavior of anchored vessels: bay of Algeciras, Bilbao, Las Palmas, Ría de Ares, Huelva, San Cibrao, etc.
- ▶ Analysis of incidents and maritime accidents: stranding of ships on the beach of El Saler, accident of FFC in Tarifa, stranding of the Cajonero Agronauta on the coast of Málaga, etc.
- ▶ Wind turbine towing studies: R+D+i CAPEMA and R+D+i TELWIND projects.

Maritime Experimentation Laboratory: Experimental Hall



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The Centre for Studies on Ports and Coasts of CEDEX has a test experimental hall with large facilities for conducting tests on a reduced-scale physical model.



General view of the test hall.

Experimental Hall

Hall size: 115 x 71 x 8 m

Permanent facilities. Type and size:

Multidirectional wave tank:
34 x 32 x 1.60 m

Large wave and wind flume:
90 x 360 x 6 m

Wave tanks (2 units):
45 x 6.50 x 2 m y 35 x 6.50 x 1.30 m

Wave flume: 36 x 3 x 1.50 m

Wave flume: 51 x 1 x 1.50 m

Wave and current flume:
20 x 1.20 x 0.80 m

Central Area: 4,000 m² for 3D tests

The experimental hall has an area of 8,000 m², without intermediate pillars, which allows the flexible use of the available area. For its activity, it has the support of auxiliary workshops for mechanics, carpentry, manufacture of parts for tests, electronics, and instrumentation.

The permanent test facilities –tanks and flumes– occupy the perimeter of the hall, leaving its central area free for temporary 3D models built *ad hoc*.

The experimental hall has facilities and equipment for the generation of marine energy (waves, tides, wind and currents). Tanks and flumes have their main application in tests of maritime structures: breakwaters and piers, terminals in the open sea and offshore structures, temporary phases and singular elements, as well as coastal engineering studies using physical models with a movable bed.

In these facilities, environmental tests are also carried out, such as studies of effluents from desalination plants

and treatment plants or hydrocarbon discharges, influence of vegetation on the waves, among others.

The central area of the hall, free of facilities, is used to carry out wave disturbance and long-wave port tests, and docked ships tests, the objective of which is related to the design of the plant of port facilities from the point of view of operational conditions. Some tests on beach with movable bed are also carried out in this area.

The experimental hall is served by water networks fed by two tanks of 1,000 m³ each, for its reuse in successive tests, as well as energy and data networks. Likewise, its surface is covered by 1,500 kg overhead cranes for construction tasks and operations in the exploitation of models. It too has a set of elevated walkways for overhead observation.

Aquatic Ecology Equipment

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The Area of Water Environment of the Centre for Hydrographic Studies has the necessary field and laboratory equipment and instruments to investigate continental aquatic ecosystems, and to carry out a wide range of studies in the field of limnology, applying and developing new techniques and protocols aimed mainly at understanding and evaluating the response of these ecosystems to environmental pressures or changes.



Joint sampling of the Spanish and Portuguese teams at the monitoring station of the Portuguese Water Agency in the Alqueva reservoir. Boat with navigation equipment acquired in 2019.

A. Fieldwork and Sampling Equipment

- Platform for obtaining sediment cores and samples with piston and percussion system (Mod. UWITEC Piston Corer).
- Multiparameter Sonde YSI Mod. EXO2 with following sensors: depth, temperature, conductivity, pH & ORP, dissolved oxygen optical sensor, turbidity, total algae (chlorophyll) and phycocyanin/phycoerythrin.
- Electric fishing equipment 1,3 kW, 300/500 W and 940 V pulses, with engine Honda 4T GXV50 6700 rpm.
- Outboard boat Whaly 500R Professional with echo-sounder-plotter Garmin, GPS navigation system and a manual operated winch for different samples acquisition systems for limnological works in reservoirs, lakes and estuaries.



B. Microscopy Room

- Optical microscopy for taxonomic analysis of aquatic organisms with stereoscopic and inverted microscopes (Leica equipments), coupled to an image capture system and digital analysis. Refrigerated incubator, rotary evaporator and accessories for toxicity bioassays.
- Electron microscopy. ZEISS scanning electron microscope for taxonomic determinations of aquatic organisms.



Above. Obtaining sediment cores in a frozen lake with piston running and percussion on a platform.

Below. Integrated water sampling from the photic zone of a lake.

Hydraulics Laboratory

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Las instalaciones del Laboratorio tienen por objeto la experimentación en modelo físico a escala reducida de estructuras hidráulicas y actuaciones fluviales en el ámbito de las aguas continentales, además de la realización de estudios de hidráulica ambiental. Complementariamente a los trabajos de asistencia técnica especializada, se desarrollan diversas líneas de investigación aplicada en materias de interés para la ingeniería hidráulica española.



General view of Hall I.

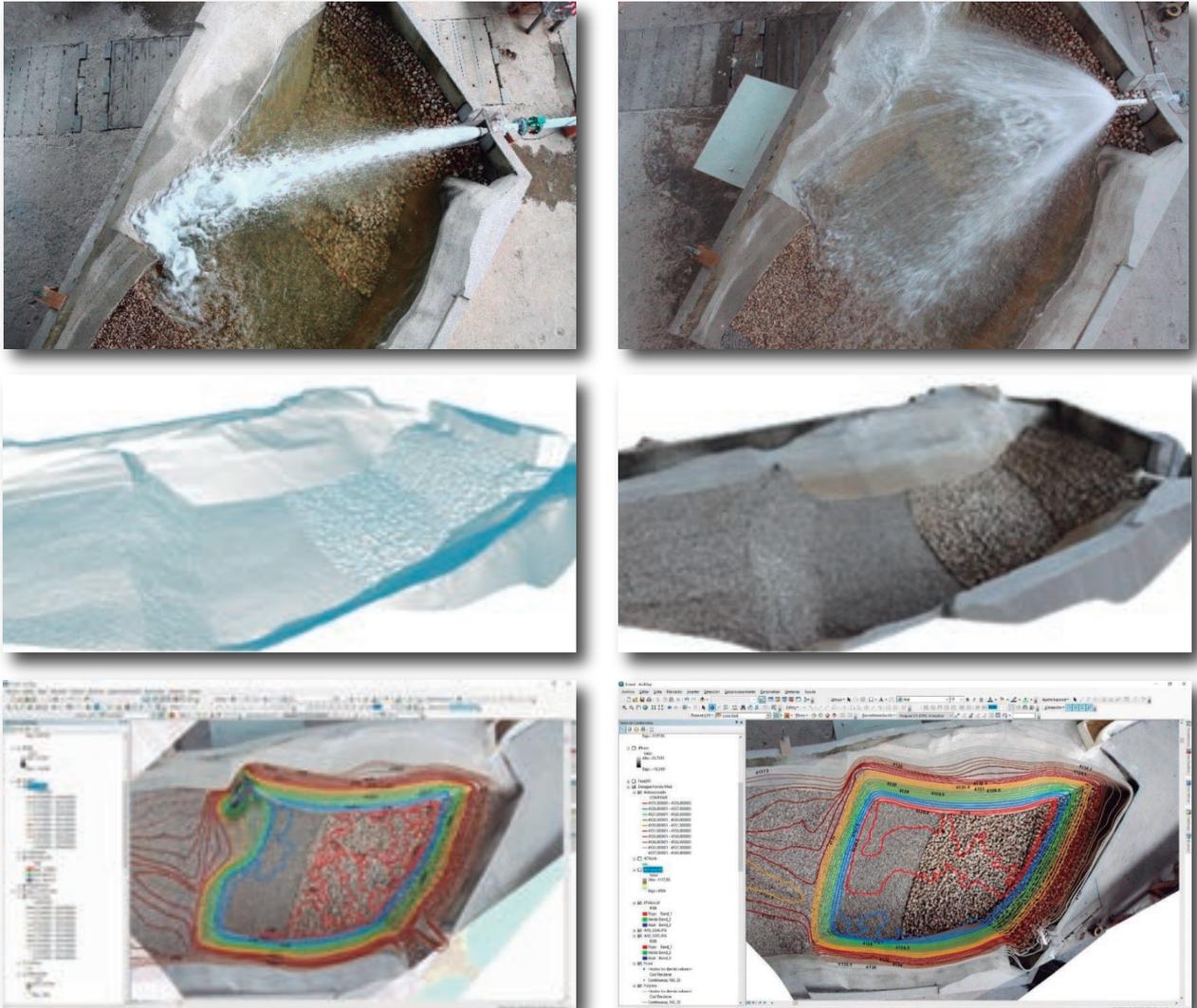


Hall II.

Facilities

1. Hall I (1,800 m²) to undertake physical model studies of hydraulic structures in the scope of inland waters.
2. Hall II (6,000 m²) to undertake physical model studies of river modelling. Automatic sediment control dispenser. There is a pumping station with a capacity of 650 l/s for the physical model studies in the two halls.
3. Fish ladder.
4. Model testing channels. The laboratory has three

- variable slope channels: two of 0.25 x 0.40 m (of 6.10 and 7.50 m length) and one of 0.40 x 0.60 m (12.00 m length); and two horizontal channels: one of 1.00 x 1.00 m (50 m length) and one of 1.50 x 1.50 m (100 length). The maximum flows vary between 25 and 500 l/s.
5. Installation for the experimentation on stepped spillways, forced aeration spillways and stilling basin optimization.
6. Experimentation on wedge-shaped protections for rockfill dams.



Examples of photogrammetric restitution of a stilling basin (Angostura Dam, Perú).

7. High tanks for bottom outlet testing.
8. Installation for special spillways testing (labyrinth, piano key, etc.).

Equipment and Instrumentation

The Hydraulics Laboratory has all the necessary equipment for physical model studies, and for registering the hydraulic variables. Equipment that should be highlighted:

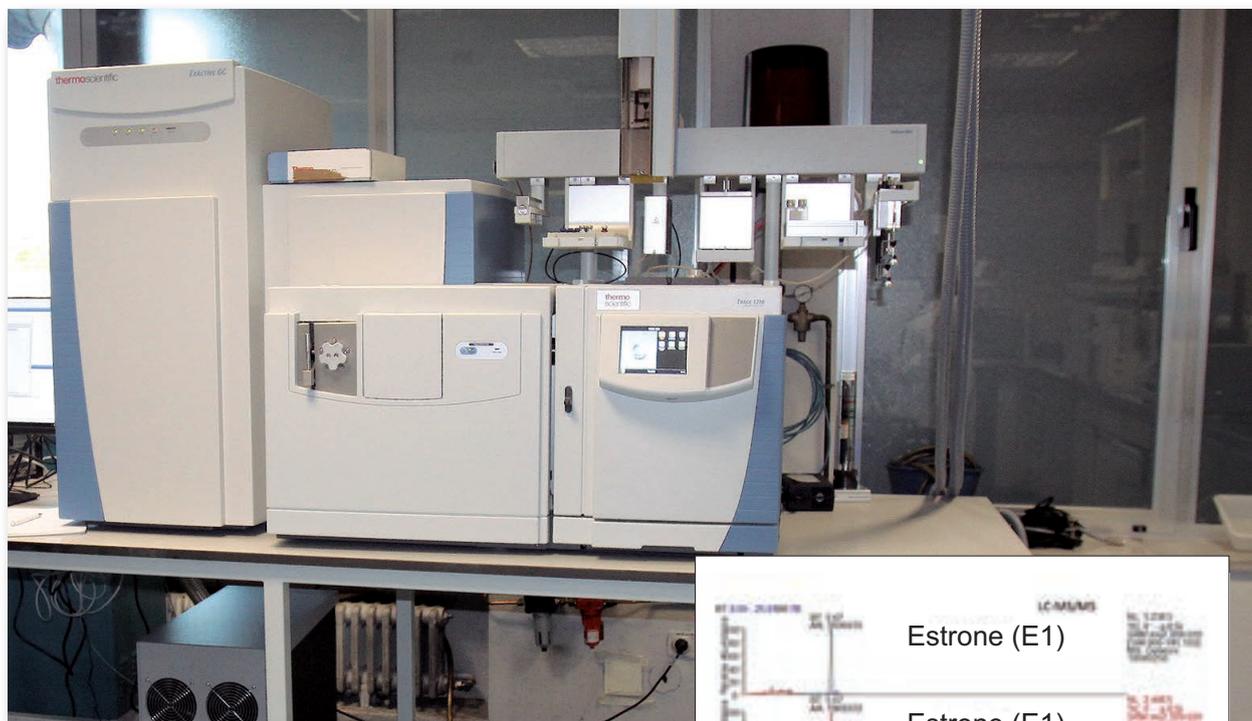
1. Motorized high-speed valve with electronic control for pneumatic closing in less than 3 s.
2. Photogrammetric equipment for 3D reconstruction of physical models.
3. 3D scanner (owned by CEDEX's Centre for Studies on Ports and Coasts).
4. Particle Image Velocity (PIV). High-speed imaging equipment with laser light assistance for the determination of particles movement and speed.
5. Set of submersible cameras and multiple display systems.
6. Vibration measurement equipment based on accelerometers.
7. Data acquisition equipment based on PXIe bus for sampling at high speed and high sensor density.
8. 3D laser printer (additive digital manufacturing equipment based on thermoplastics for rapid prototyping).
9. Drones (shared with the other centres and laboratories of CEDEX).
10. Set of electromagnetic flowmeters of different diameters.
11. Ultrasonic limnimeters with a precision of mm.
12. Pressure sensors (up to 500 readings per second). Individual sensors or a Scanivalve pressure equipment with multiple transducers.
13. Acoustic Doppler Velocimeter (ADV) probe to measure 3D water speed.

Water Quality Laboratory

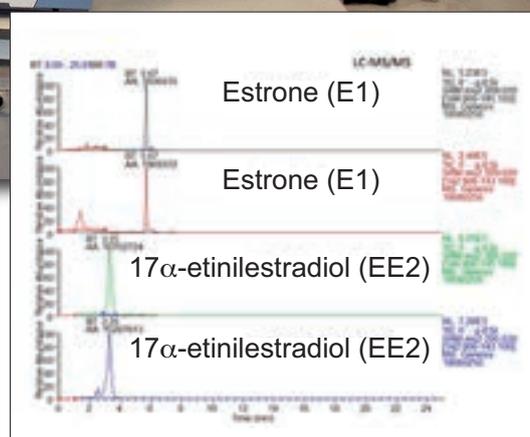
Contact: ana.m.alonso@cedex.es



In 2019, the Water Quality Laboratory of the Centre for Hydrographic Studies of CEDEX has acquired a high-resolution mass spectrometer with Orbitrap technology. This hi-tech equipment puts the laboratory at the forefront for the detection of contaminants and substances included in the research control program defined in the Royal Decree establishing the criteria for monitoring and evaluating the status of surface waters and environmental quality standards and in the Water Framework Directive.



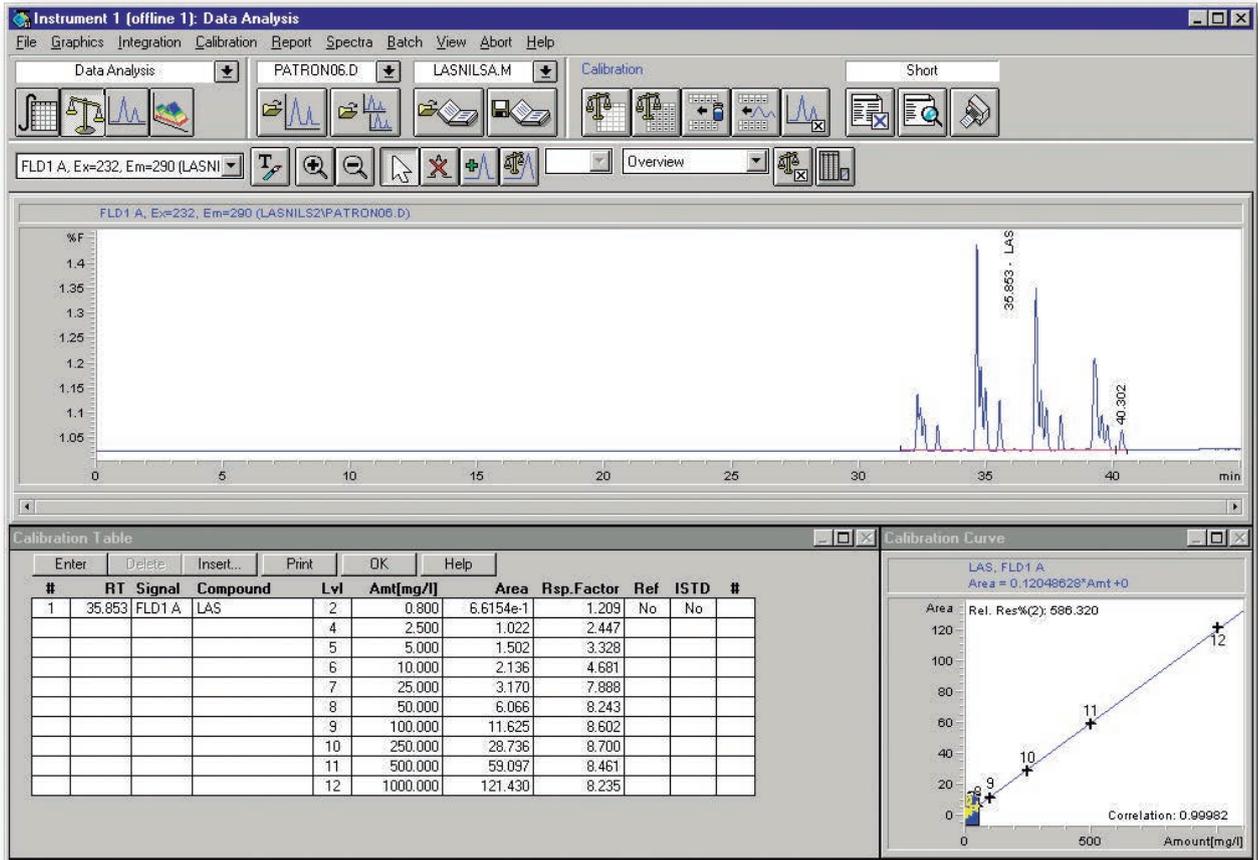
High resolution mass spectrometer with Orbitrap technology.



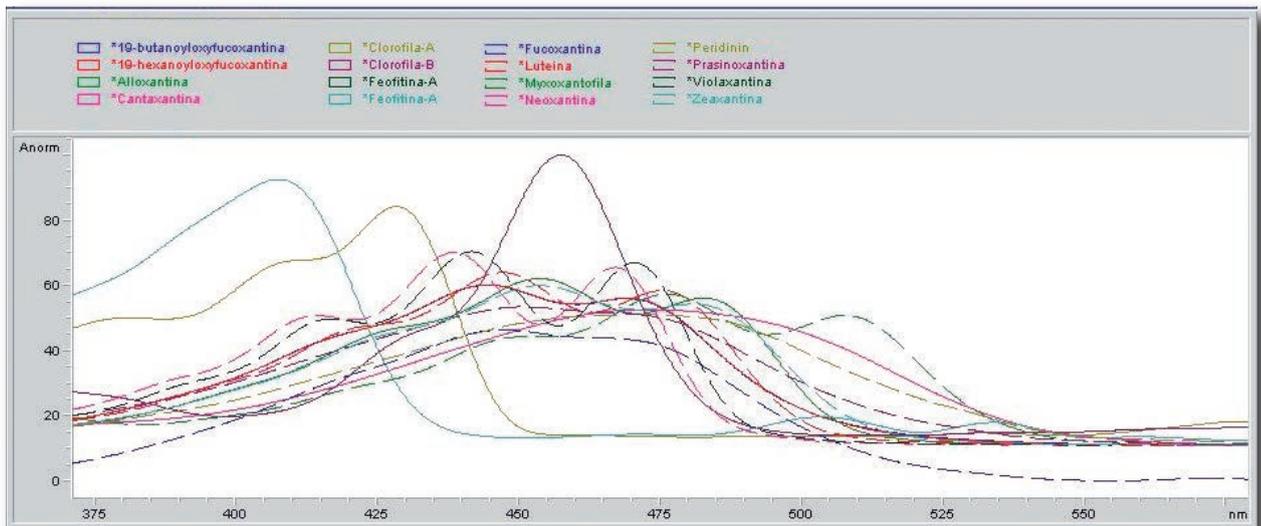
The spectrometer is equipped with:

- A gas chromatograph for the separation of the different analytes with double channel for injection with distribution / without distribution (split / splitless), and in large volumes (PTV).
- An intelligent injection system that allows samples to be injected in three ways: liquid injection (SSL), headspace injection for the analysis of volatiles, and solid-phase microextraction (SPME).

The equipment can work in high resolution (120000 m/z) for obtaining exact masses with an absolute mass error of 0.002 Da (5ppm), allowing the identification and quantification of known compounds at trace levels and the presence of unknown compounds in the sample. With this equipment, different emerging substances can be determined such as compounds from the Watch List, persistent organic compounds, volatile and semi-volatile, pesticides, dioxin fertilizers, PBDEs, nonylphenols, among other water pollutants.



Analysis of linear alkylbenzene sulfonate (Linear Alkylbenzene Sulphonate-LAS) by high performance liquid chromatography (High Performance Liquid Chromatography-HPLC).



Wavelengths of pigments analysed by High Performance Liquid Chromatography (HPLC) with Diode Array detector.

Water Quality General Laboratory

Analysis of chemical compounds in water and other water matrices.

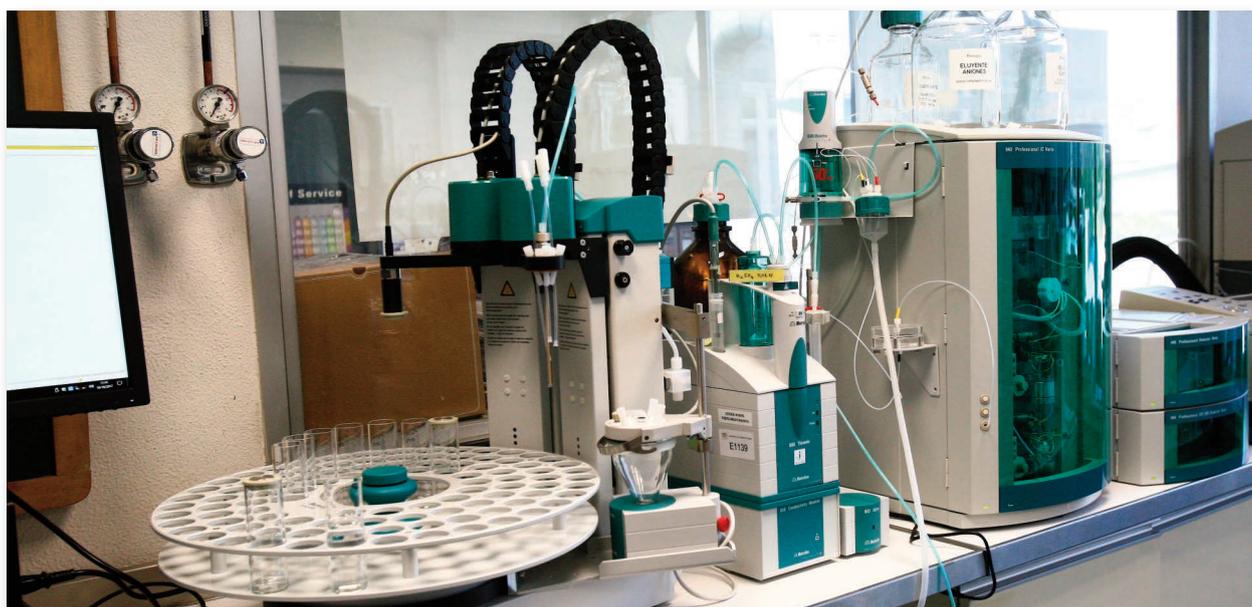
- Ion chromatography with titrator and UV/VIS detectors, conductimeters and amperometric for the analytical determination of major components present in water (IC).

- Total carbon and nitrogen analysers of solid and liquid samples (COT-NT).

- Continuous segmented microflow multi-analyser for the analysis of forms of nitrogen, forms of phosphorus, cyanide, phenol and detergents.



High resolution liquid chromatograph with high resolution triple quadrupole mass detector and E-quan system for direct introduction of liquid sample (HPLC/MS/MS). It is used for the study of emerging substances (cyanotoxins, drugs, pesticides, endocrine disruptors, PFOs, etc.). With this equipment, the Water Quality Laboratory has been a pioneer in developing several methodologies that have been used to participate in numerous works



Metal Analysis Laboratory

- Continuous Flow Injection Mercury System (FIMS) and Atomic Absorption Spectroscopy (AAS) for the analysis of Hg and metals in water.
- Atomic emission spectrometer with ultrasonic nebulizer that uses the Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) analytical technique. Multi-elemental analysis of metals.
- Mercury analyser for solid samples.

Laboratory for the Analysis of Organic Compounds

Extraction systems, sample systems and high-tech analysis equipment.

- Accelerated solvent extractor (ASE).
- Solid phase extraction for liquid samples (Autotrace).

- Power-Prep system of automated fluids for the extraction and purification of samples (dioxins, PCBs, pesticides, PAHs, etc.).

- High resolution liquid chromatograph with triple quadrupole high resolution mass detector and E-quan system for direct introduction of liquid sample (HPLC/MS/MS).

- High pressure liquid chromatograph with fluorescence detectors and Array Diode and Pickering post-column derivatization system (HPLC).

- Gas chromatograph coupled to quadrupole mass spectrometer with purge and trap (P&T/GC/MS).

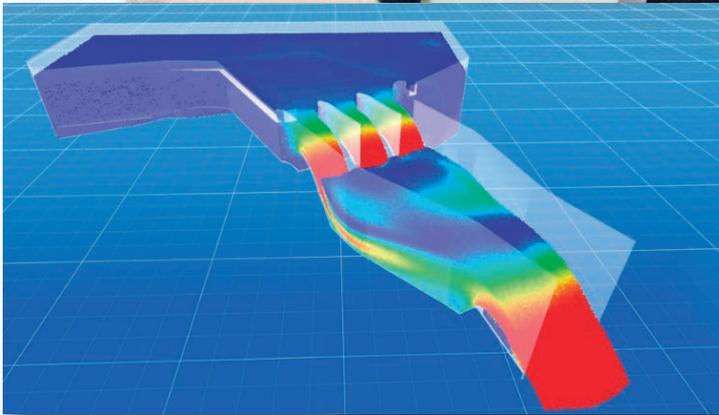
- High resolution mass spectrometer with Orbitrap technology.

Virtual Reality Room

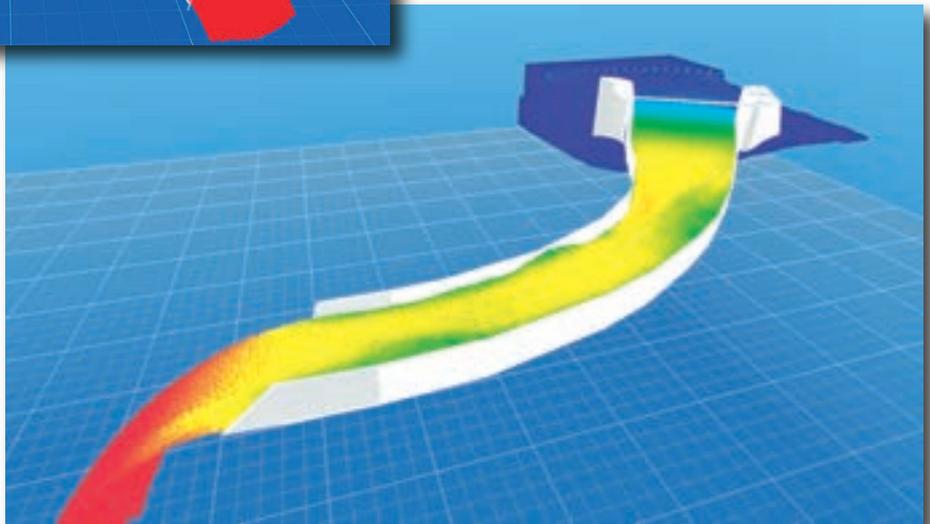
Contact: david.lopez@cedex.es



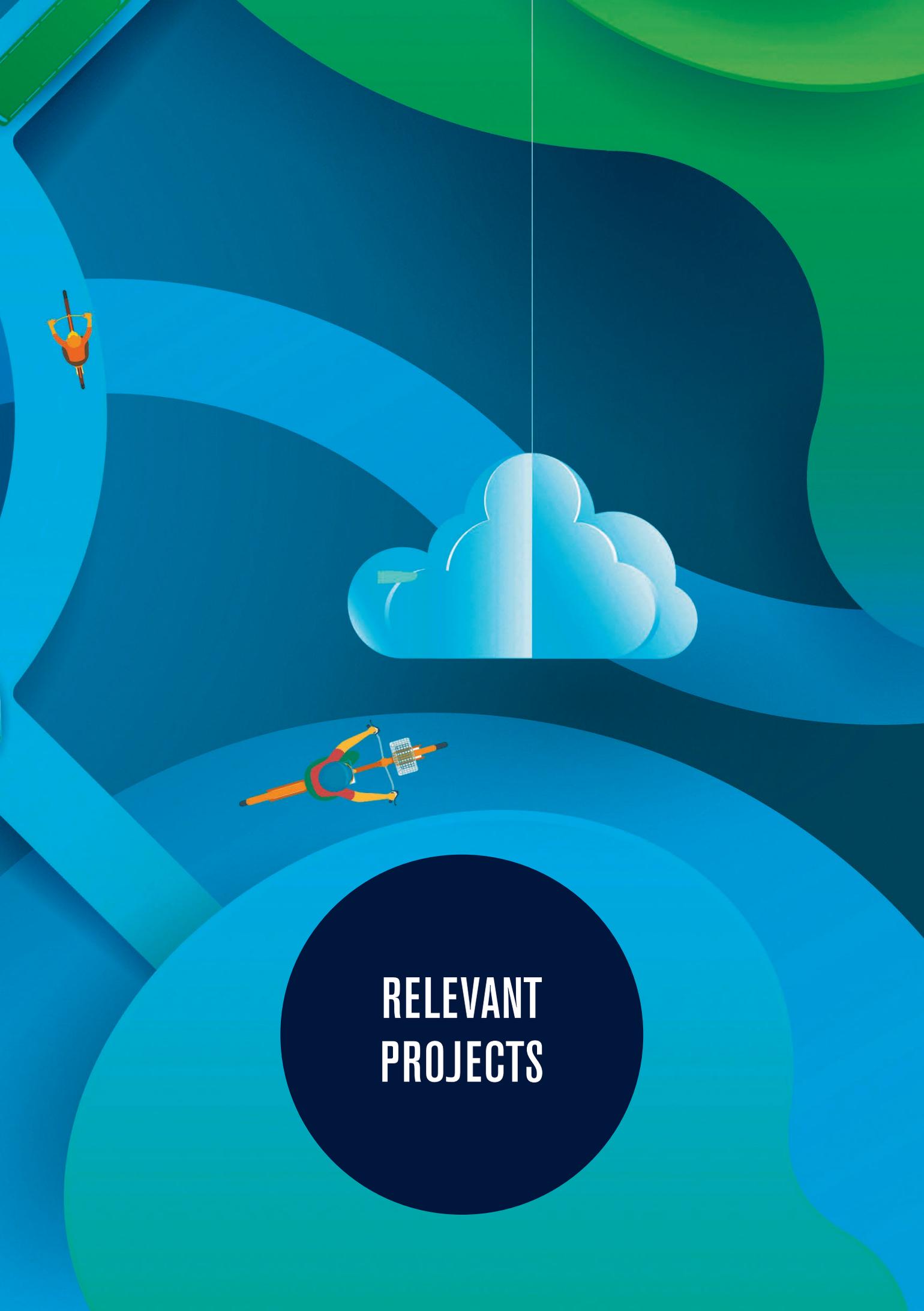
In order to visualize numerical 3D models by stereoscopic techniques, the Centre for Hydrographic Studies has a virtual reality room to ease 3D model analysis and rendering. The room has two technological mechanisms to produce 3D stereoscopic vision, both passive and active systems.



Visualisation in the Virtual Reality Room of the results of the mathematical 3D modelling of the spillways of the Barcena (CH Mino-Sil, above), Palmaces (CH Tajo, centre), and Camporredondo (CH Duero, below), dams.







**RELEVANT
PROJECTS**

Manual on the Use of Crumb Rubber From End-of-Life Tires (NFVU) in Bituminous Mixtures 2020 - 2nd. Edition Revised and Updated

Contact: rafael.jimenez@cedex.es



Through the initiative of the Directorate-General of Roads of the Ministry for Transports (MITMA), it was launched in 2018 the revision of the *Manual on the Use of Crumb Rubber from End-of-Life Tires (NFVU)*. Its first edition was published in 2007.

Today, NFVU crumb rubber is still considered as waste material. However, its potential as a modifier of binders and bituminous mixtures has been well proven for more than 15 years of use on Spanish roads, providing certain improvements over conventional bitumens. Such application enables an important means of recycling this waste, contributing to its reuse and, therefore, to the establishment of a circular economy environment.

Throughout this period there has been an evolution in the techniques for its use, which has led to the appearance of new products. Hence the necessary updating of the manual, whose function is to collect all the experience of use accumulated over the years, thus constituting a useful reference for technicians who intend to use these products and procedures.

The review is being carried out by a technical committee, participating representatives from all industrial sectors involved: used tire rubber recyclers and producers of crumb rubber, binders and asphalt mixtures manufacturers, along with technicians from Administrations and Universities, all of them with extensive knowledge and experience in different aspects related to the production of NFVU crumb rubber and its derivatives, as well as its incorporation into asphalt mixtures, and the use of these products on-site.



Laying and compaction of asphalt mixtures with NFVU crumb rubber.



The publication of the second edition of the manual, as a CEDEX Monograph, is scheduled for the last quarter of 2020.

Landfill of end-of-life tires. Source: *Diario de Valladolid*.

The CLARITY project

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The CLARITY project is funded by the EU under the umbrella of the Horizon 2020 programme, in the area of climate action, environment, resource efficiency and raw materials (Work Programme SC5).



To accomplish this objective, a website is being designed where any user can assess the impacts and risks derived from climate change, both in transport and urban infrastructures. The EU is fully aware that climate services are essential to improve the resilience of infrastructures.

The project started in June 2017 and is now coming to an end. A large amount of climatic and geographic data have been collected, future projections of all relevant climatic variables have been calculated, and specific methodologies to assess the vulnerability and impacts of the exposed elements have been developed. In this process, several workshops and seminars have been held to ensure the participation of all stakeholders.

Four demonstration cases are showcasing CLARITY climate services. Three of them have been implemented in cities of different climatic, regional and hazard contexts in Italy, Sweden and Austria. The fourth demo case is located in Spain; focusing on the possible impacts of climate change in a four-lane-highway section in the province of Guadalajara, from pk. 62 to pk. 135.

For road transport infrastructures, the climate service will provide the users with the following information: projections of the most relevant climatic indices related to road design, maintenance and operation; approach to the expected impacts and risks of climate change variability in road infrastructures; and proposal y adaptation measures.

CEDEX, Acciona Ingeniería, AEMET, ATOS, and Meteogrid are taking part in the Spanish demo case.

CLARITY's objective is to provide support for studies and implementation of strategies for mitigation and adaptation to climate change

At this moment, the validation of the climate service functionalities is being performed in the four pilot cases

Climate change is underway and adaptation and mitigation actions are needed in all areas of civil engineering. Inspired by this, CLARITY has become an example of collaboration between different laboratories within CEDEX

Project duration: 39 months

From 1st June 2017 to 31st August 2020

With the participation of 17 companies and organizations

www.clarity-h2020.eu



Climate service implemented by the CLARITY project where climate change impacts studies will be available.

Performance Indicators in Main Shadow-Toll Road. Concession Verification

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CEDEX is providing specialized technical assistance to the Directorate-General of Roads of MITMA for the verification and monitoring of quality and performance indicators in highway concessions.



CEDEX FWD checking the bearing capacity in a road section.

Given the outstanding economic impact these indicators have, the Ministry relies on the support of CEDEX to verify that the values proposed by the concessionaires correspond to the state of the road and, therefore, are valid

At the beginning of 2000, within the framework of the PEIT (2005-2020), the need to undertake a series of actions to update, refurbish and maintain the so-called “first generation concessions highways” was identified. Given its high cost, the concessional model was chosen, which has been applied to the corridors from Madrid to Burgos (A-1), Zaragoza (A-2), Alicante (A-3 and A-31), and Seville (A-4). These concessions have a length of 993 km and carry approximately 14% of the total traffic of the Spanish main road network (RCE). The annual budget is around 300 million euros, which amounts to approximately one third of the total fund allocated to the maintenance and exploitation of the RCE. These figures highlight the importance of these contracts.

The remuneration to the concessionaire companies consists of a monthly fee that, basically, is calculated as a product of a unit rate for the traffic. This unit rate is modulated by correction factors, up or down, that are related to the condition and quality of the road, quantified through performance and service indicators. For the aforementioned indicators there are thresholds that imply bonus or discounts depending on the achievements.

Since the indicators refer to technical parameters whose quantification implies some complexity, CEDEX assessment was sought after. Although there are regulations and standards in this realm, their implementation in the case of first-generation highways have required the technical assistance of CEDEX to clarify different aspects related to it.

CEDEX is assessing and checking the most relevant indicators, both from a road safety point of view and an economic perspective. In short, it's a matter of guaranteeing the good condition of those sections of road whose maintenance and operation, according to the implemented concession model, corresponds to the concession companies.

Indicators checked by CEDEX

Centre for Transport Research

- Skid resistance
- Longitudinal evenness
- Capacity bearing
- Cracking

Materials and Structures Laboratory

- Road marking retro-reflection
- Vertical signs retro-reflection

The quality thresholds set for first generation highways are more demanding than the average standards that are found in the network in service. CEDEX is in charge of verifying that the condition of the highways indeed corresponds to that declared by the concessionaires

Duration of the contract: 36 months
From 15th July 2018 to 15th July 2021

REPARA 2.0 Project - Installation of a Weigh-in-Motion (WIM) of Road Vehicle System



Contact: jesus.leal@cedex.es

The REPARA 2.0 project deals with the development of new techniques and information systems for the sustainable rehabilitation of road pavements.



Execution of the pavement cut with a diamond blade saw to excavate the grooves where the sensors are inserted, and placement and sealing of the piezopolymer sensor using epoxy type resin with accelerator.

This project includes a work topic that is based on the assumption that the instrumentation of pavements can be a powerful tool for the investigation of its behavior. Therefore, this project aims to define and deploy a new advanced instrumentation scheme for dynamic monitoring of pavement condition, which includes the use of sensors embedded in the pavement, as well as progress in the use of wireless communications to transmit data.

In this respect, a weigh-in-motion (WIM) system has been installed on the A-1 motorway, at the municipal district of El Molar (Madrid), in the right lane of the carriageway towards Madrid, whose objective is to provide comprehensive and permanently updated information on the gross weights and axles loads of the vehicles that circulate on the highway, which constitutes fundamental input data in the prediction models of the damage process of a road pavement.

In order to carry out the installation on the road of a WIM system, the pavement must be cut with a diamond blade saw to dig some grooves about 5 cm deep, where the piezopolymer sensors and the inductive loop cable are placed. Once inserted, the grooves are sealed with epoxy resin for the weight sensors and asphalt mastic for the loop.

The installed WIM system consists of two linear weight sensors of piezopolymer type that cover the entire lane width, an induction loop to detect the presence of vehicles, an electronic unit for recording the signals provided by the sensors, as well as for their processing and storage, and a solar panel with the corresponding batteries to provide the electrical energy supply for the operation of the system.

The application of data obtained with this WIM system allows to obtain a detailed and in-depth knowledge of the weights and loads of heavy vehicles travelling on the road network, which permits to optimize the predictive maintenance of the road infrastructure, as well as to obtain up-to-date statistical data of the loads that road pavements must resist, thus facilitating a more accurate structural design of these.



Final appearance of the weight sensors and the induction loop once installed on the roadway.

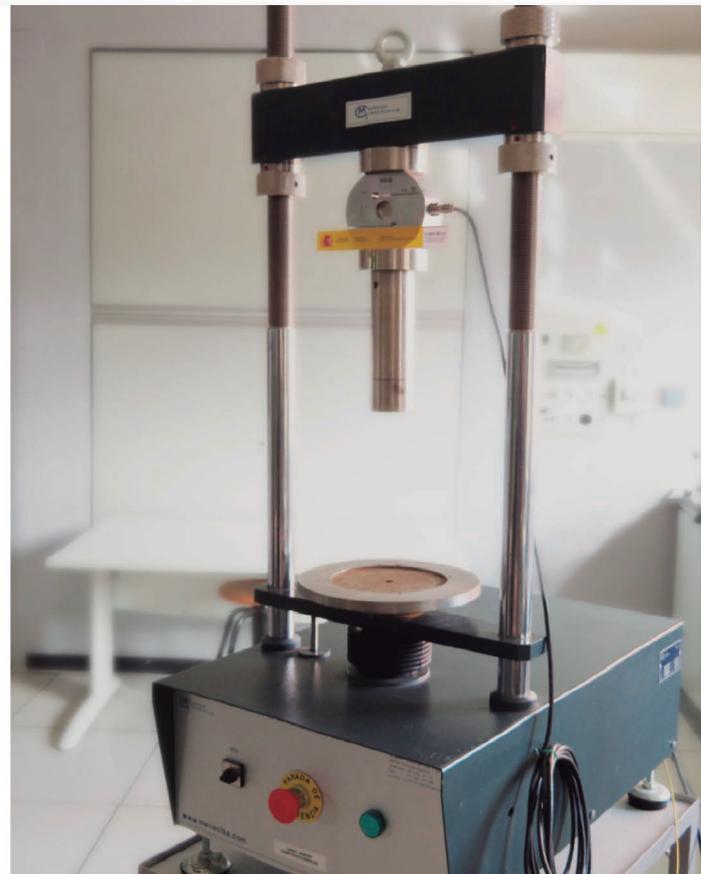
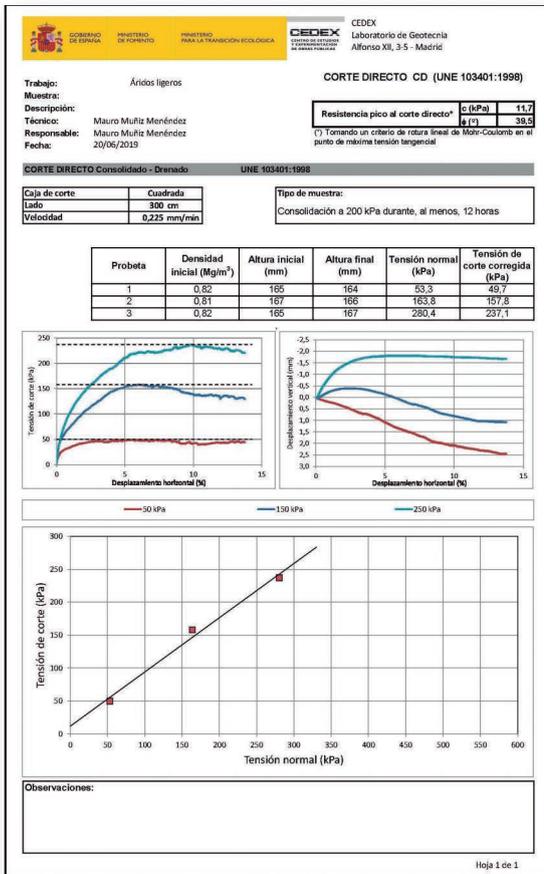
WIM systems are able to measure the gross vehicle weights and the loads of each one of its axles, of all traffic travelling on a highway at the normal travel speed, without any interference in its movement, which makes it possible to have data input for the design and preventive maintenance of road pavements

Geotechnical Characterization of Light Aggregates Impregnated in Molten Salt

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In this work, the geotechnical characteristics of a light aggregate affected by a high-temperature molten salt were analysed. This aggregate has been used as a foundation material in a solar thermal plant.



The study focused on analysing the influence of both elevated temperatures and salt impregnation on the mechanical behaviour of the filler material.

The study of non-conventional materials subjected to anomalous environment and loads make the standardized tests commonly used in geotechnics useless. This situation makes mandatory the *ad hoc* development of new test methodologies. In this study, CEDEX Geotechnical Laboratory collaborated with the LaMeRock research group of A Coruña University in the development and carrying out of some non-conventional tests, which allowed to analyse the behaviour of these materials in the same conditions as *in situ*. It was remarkable the development of test at high temperatures.

Also, it's been studied other light granular aggregates subjected to the same environmental and mechanical situations. This part of the study will provide designers with a wider variety of alternatives allowing to improve the safety and minimizing the risks in future similar projects.

Main tests carried out at CEDEX Geotechnical Laboratory

- Direct shear test with shear boxes of various sides (up to 300 x 300 mm)
- Confined consolidation tests with load-unload-reload cycles and stress and strain control
- Size distribution determination
- Density measurement by Helium Pycnometer

Carchuna Landslide (1.5 million m³)

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This work is an example of the activity of the Geotechnical Laboratory of CEDEX regarding the study and design of stabilization measures to correct pathologies concerning linear infrastructures. It's about a recent major landslide in the A-7 highway near Carchuna (Granada), which has caused significant deformations and damage to the road.



The cut slope was excavated in marbles and phyllites. It's 80 m high and 370 m long. Wide traction cracks appeared on the hillside over the top level of the cut. These cracks were 225 m away from the road. The volume of material mobilized by the instability exceeded 1.5 million m³. An extensive research campaign was performed, consisting of 14 boreholes, which included the installation of inclinometers and piezometers, and 120 topographic control points. The complexity of the hillside motion kinematics, stratigraphy and orography justified the convenience of performing some numerical models that included both 2D, more common, and 3D calculations. In this specific case, the 3D models reproduce the problem complexities in a much more accurate way.



Mesh of the 3D model after the excavation of phase 1.

Due to the magnitude of the unstable mass, a stabilization by phases was proposed. The first phase aimed to achieve a slight improvement in overall stability and to prevent that a future evolution of the instability would be affected by the highway. It also aimed to gain time for the implementation of the major correcting measures to control the slope stability that would be included in later phases. In this first phase, a "fusible zone" was created by excavating a band of terrain, about 20 m wide and parallel to the road, at the toe of the slope. The volume excavated in this area was small compared to the material removed at the top of the slope, so that the unfavourable effect of the excavation at the toe would be much lesser than the stabilizing effect caused by the excavation at the top.

Once the first phase was concluded, it was observed that the hillside motion speed remained high (movements of about 500 mm/year), but the deformations at the toe of the slope were now located within the "fusible zone" minimizing the impact on the highway platform. As a second phase of stabilization, the plan included an excavation at the top of the slope, complementary to the initial one, and the execution of a network of drainage wells, equipped with pumps or communicated with each other by gravity. Structural elements were also designed at the outer edge of the "fusible zone". Their aim is to protect the highway by avoiding that the bottom of the sliding mass could affect it.

Stabilization of a large landslide affecting a highway

An extensive research campaign was performed

Numerical models included both 2D and 3D calculations

A fusible zone has been designed to limit the impact on the highway (first phase of stabilization)

Work Conducted in the Editorial Committee of the Future Eurocode EC-7

Contact: jose.estaire@cedex.es



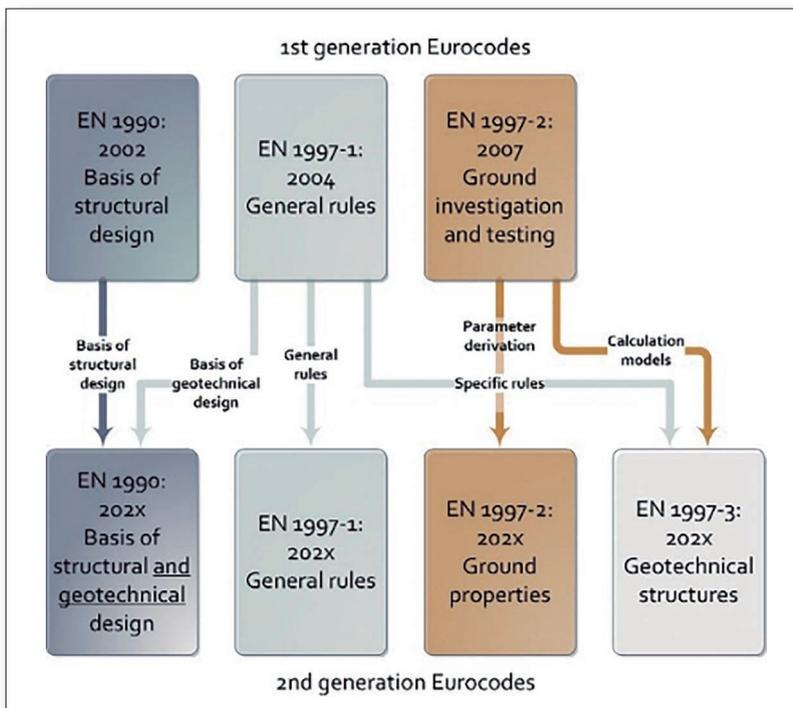
Eurocode EC7. European standard published by the European Committee for Standardization (CEN), related to the Geotechnical project for structures in building and civil works. Its wording is collected in EN standard format, specifically in EN1997.



Meeting of several SC7 work teams at the meeting held in Delft in December.

Development of geotechnical projects is, logically, affected by globalization, which involves clarifying the process and setting common application guidelines. Within this framework, the European Union has the Structural Eurocodes (EC) that have the mission of unifying criteria and regulations in matters of design, calculation and dimensioning of structures and prefabricated elements for building and civil works.

First versions of the EC were published in 2004. Six years later, the European Commission considered it necessary to start the development of those first ones, resulting in their restructuring and clarification. The entire process is being coordinated by the European Committee for Standardization (CEN).



Redistribution of Parts 1 and 2 of the current Eurocode 7 (EN1997-1: 2004 and EN1997-2: 2007) in the new Eurocodes 0 (prEN1990) and 7 (prEN1997).

EC7, referring to the Geotechnical project, is being prepared by Subcommittee SC7. José Estaire, head of the Technological Infrastructures Area of CEDEX Geotechnical Laboratory, takes part in the drafting team. Another of the tasks that have been carried out is the dissemination among the national geotechnical community of the new changes regarding the future EC7, through technical workshops that have been held at CEDEX.

One of the most relevant aspects of the new wording of EC7 is the redistribution of the current Part 1 and Part 2 of EC7 (EN1997-1: 2004 and EN1997-2: 2007) in the new Eurocodes 0 (prEN1990) and 7 (prEN1997).

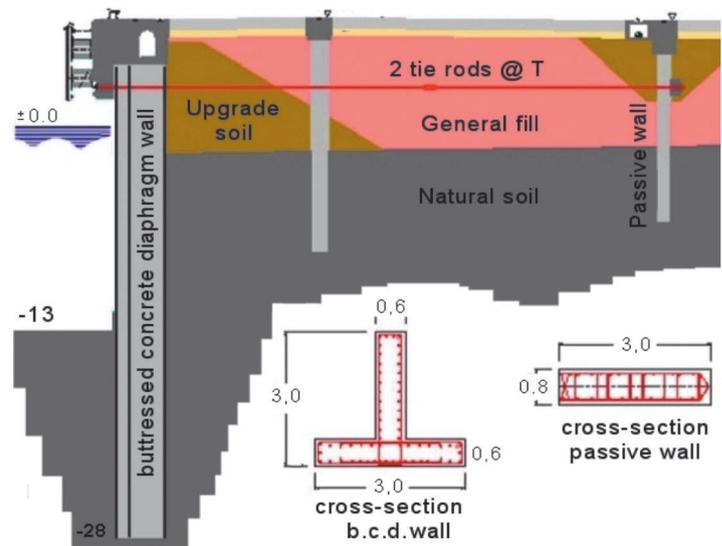
Inspection Programme for Repairing a Quay Structure: An Achored Concrete Diaphragm Wall



Contact: enrique.asanza@cedex.es

As a part of the commission launched by Puertos del Estado for technical assistance, applied research and technological development in the scope of the state-owned port system, the Geotechnical Laboratory (CEDEX) is involved, among others issues, in the detection of anomalies in a quay with a 750 m berthing line, which came into service in 2005. For over a decade, the corresponding Port Authority has periodically recorded the sudden episodes of metric sinkholes on the pavement near the cantilever beam, even though repair work has been carried out in the past.

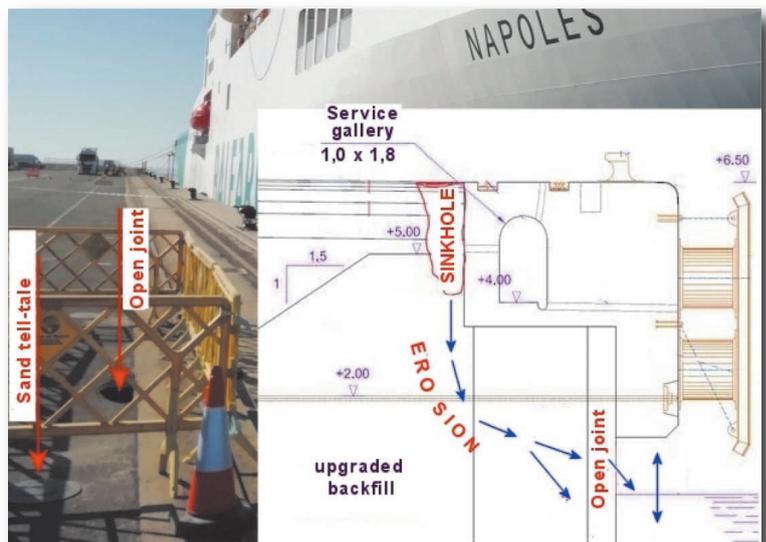
The structure of this quay is a 32 m long buttressed diaphragm wall of reinforced concrete, embedded in the seabed, leaving a berthing depth at -13m LAT. The diaphragm wall, built inland on an auxiliary approach embankment, consists of a series of “T-shaped” modules. The “T” are 3 m wide and long and 0.6 m thick, and are anchored to a conventional passive concrete diaphragm wall (0.8 m thick) by means of two steel tie bars every module. The passive diaphragm wall also serves as a foundation for the rear crane rail for containers. The general cross section is depicted in the following figure. The edge beam has a service gallery and two front crane rails.



Up to date, the Geotechnical Laboratory has been in charge of: gathering and analysing profuse historical documentation, during construction and subsequent reparation works; inspection of the quay, with the MASW technique, geo-radar and the Panda penetration equipment (with its own staff); checking the “sand tell-tales” (refillable vertical pipes with medium-size sand where the loss of soil is measured); global assessment, together with previous inspection carried out by private companies, in view of detecting incipient cavities that may eventually trigger further sinkholes; and, finally, a proposal for a specific inspection programme, both from surface and underwater. The following figure shows the erosion mechanism next to the edge beam.

Sinkholes at quays

This sort of damages is the sudden outcome on the yard pavement, generally triggered by soil loss from the backfill, which is washed out to the sea through malfunctioning joints of the wall face



ERTMS Tests of the Antequera-Granada HSL



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CEDEX Rail Interoperability Laboratory has performed in the first quarter of 2019 the train-track interoperability of the high-speed line (HSL) Antequera-Granada equipped with ERTMS L2.

The high-speed line Antequera-Granada belongs to the rail transversal corridor of Andalucía. It's a line allowing the high-speed connection of Granada with Málaga, Córdoba, Sevilla and Madrid.

It's a line designed to reach speeds of up to 300 km/h with a total length of 120 kms, and equipped with the signaling system ERTMS Level 2.

During the first quarter of 2019, CEDEX Rail Interoperability Lab has performed the interoperability tests of this HSL. These tests consist of running a simulated train equipped with a real ERTMS On Board Unit (OBU) over a simulated track equipped with the two real RBCs of the line. For this specific case, the track supplier is

Siemens and the onboard equipment used by CEDEX RIL has been the Alstom ETCS OBU BL2. The execution of the tests at the laboratory allowed to detect some interoperability incidences and, therefore, its early debugging before testing on the real line with the resulting cost-time reduction.

As an example, a problem in the process of handover between the two RBCs of the line was detected, allowing its correction before placing in service the line on 26 June 2019.



Antequera-Granada HSL.



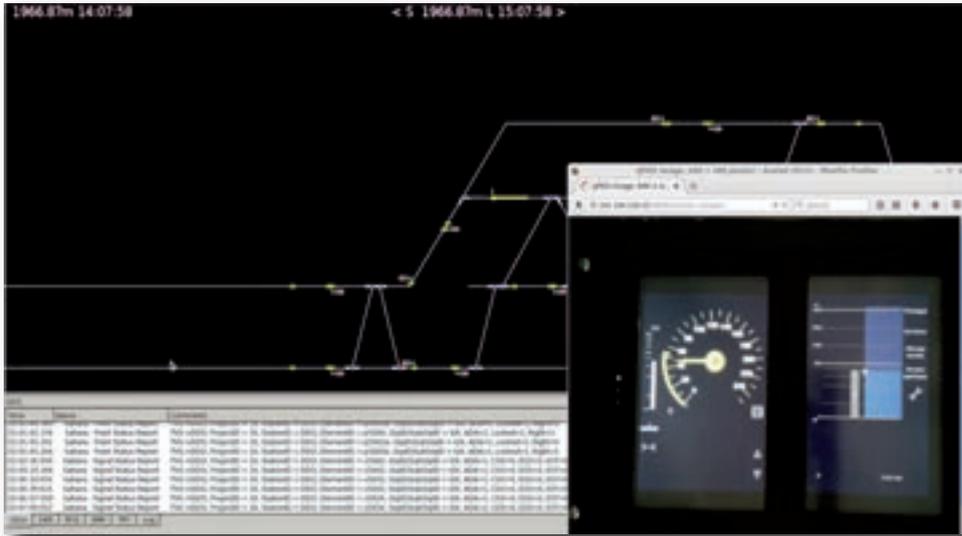
Lab tests.

Dakar (Senegal) ERTMS Line Tests

Contact: miguel.lopez@cedex.es



TER project: how to speed up ERTMS rail signaling connection between Dakar and its International Airport. The role of lab testing.



In DAKAR project lab testing at RIL has been used as a powerful and flexible tool for debugging any baseline compatibility issue between ETCS BL3 onboard (ALSTOM supplier), and track (THALES BL2), subsystems

Train movement simulation over the ERTMS line at lab.

As a matter of course, the deployment of Automatic Train Protection (ATP) systems performed on any rail national network, whatever their safety features, has been carried out by the infrastructure manager (IM) by executing all related functional, operational and system integration tests almost entirely on-site.

However, with the appearance of ERTMS not only as the European standard but also as the world's leading signaling system, a different scenario is on track. As a unique multi-supplier system, it's evident the range of possible track engineering implementations to cover such a very high level of safety and operational performances. Thus, functional tests and, consequently, the whole test process are affected for their more detailed degree and complexity. In addition, an independent partner from a different onboard and trackside supplier has to be considered when managing compatibility issues between both subsystems.

The ERTMS/ETCS L2 line in Dakar (Senegal), connecting the capital city and its airport, is planned to be installed and put into service in 2020. For this purpose, lab testing at RIL has been used as a powerful and flexible tool for debugging any baseline compatibility issue between ETCS BL3 onboard (ALSTOM supplier) and track (THALES BL2) subsystems, before on track final installation and the other rail subsystems integration tests are performed on-site (reliability, braking performances of rolling stock, etc.).

This project constitutes a demonstration on how lab environment is progressively game changing the ERTMS/ETCS rail signaling deployment process, by advancing any potential compatibility issues during earlier stages of the project cycle life. Any operational behavior involving trackside information being sent to the onboard equipment under different conditions is completely traced, and could be reproduced at any time at the laboratory.



Thales RBC (BL2) at lab.

ERSAT-GGC PROJECT (ERtms+SATellite-Galileo Game Changer)



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ERSAT-GGC (ERtms+SATellite-Galileo Game Changer) innovation project is an H2020 program European project funded by GSA (European Global Navigation Satellite Systems Agency). Its main objective is to contribute to the standardization of the certification process of the satellite assets to allow the adoption of GNSS (Global Navigation Satellite System) in the ERTMS standard.

The application of GNSS in ERTMS is based on the use of **virtual balises** to provide positioning information in specific track sections, in order to reduce the number of physical balises and to improve the position uncertainty.

During ERSAT-GGC project, a track area classification process with respect to the expected presence of local GNSS hazards along the railway lines has been specified, and a toolset has been developed so as to classify the different track sections as suitable or not suitable for the use of virtual balises, by analysing different effects on GNSS signal (multipath, EMI, NLOS, etc.).

Three measurement campaigns for data collection have been executed in Italy, France and Spain, in order to validate the classification process. The line selected by ADIF in Spain is the track section Almorchón-Alhondiguilla, and the data collection instrumentation was installed in a laboratory train from ADIF.

The measurement campaign was executed with the participation of ADIF, CEDEX, INECO, DLR and IFSTTAR, and collected raw data registers were analysed at CEDEX Railway Interoperability Laboratory with the toolset developed during the project.

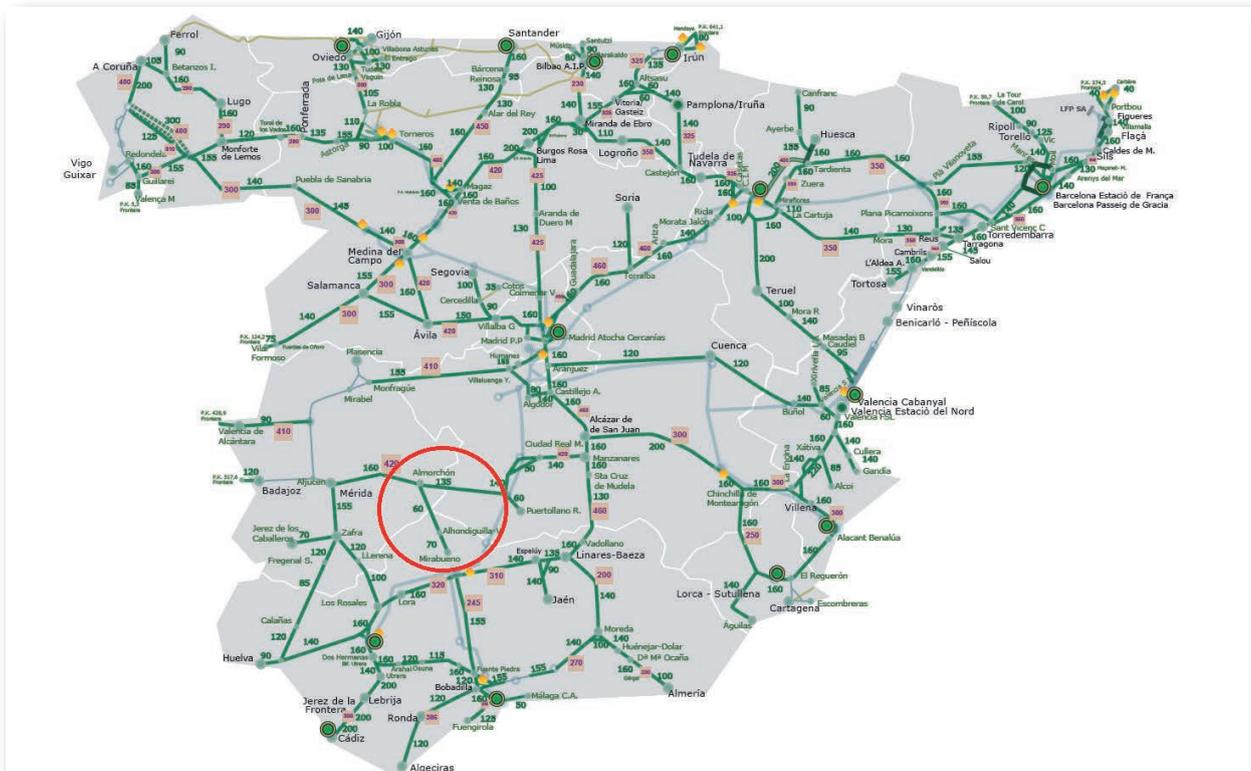


ERSAT GGC

Project duration: 2 years (November 2017 - November 2019)

14 partners from 5 European countries: Italy (RFI, Hitachi STS, RINA, Trenitalia, RadioLabs, Italcertifer, Bureau Veritas), France (IFSTTAR - SNCF), Spain (ADIF, CEDEX, INECO), Germany (DLR) and Belgium (UNIFE)

Three measurement campaigns have been executed in Spain, Italy and France



Location of ADIF test line. Source: ADIF.



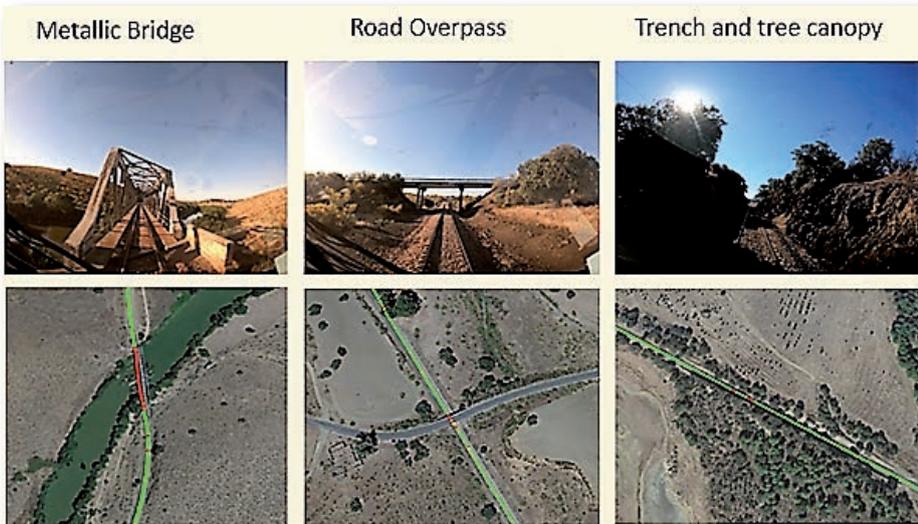
Lab train from ADIF stationed at Alhondiguilla.

Fish-eye camera in Lab-3 car

GNSS antenna in Lab-2 car



Detail of the installation of fish-eye camera and GNSS antenna on the train roof.



Examples of classification results.

Conclusions

- The Enhanced ERTMS Functional Architecture, suitable for the introduction of the GNSS Positioning technology through the inclusion of the **virtual balise** concept, has been reviewed
- A toolset to classify the railway track sections as suitable/not suitable for the use of virtual balises use has been specified and developed
- Execution of measurement campaigns in three different countries (Spain, Italy and France) to support and validate the classification process and the developed toolset
- Railway laboratories participating in the project, being one of them CEDEX, have integrated the classification toolset and analysed the collected data to classify the surveyed lines

Certification of the ETCS Onboard Equipment From Hitachi (Ansaldo)

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The CEDEX Rail Interoperability Laboratory has tested during 2019 the Hitachi (formerly Ansaldo) ERTMS On Board Unit that will circulate throughout France's high-speed lines.



TGV equipped with Hitachi EVC.

Hitachi ETCS onboard equipment has been technically validated in the Rail Interoperability Laboratory (RIL/LIF) at CEDEX. This equipment commands the train movement in track, and it's part of the European system (ERTMS) for controlling and managing the railways traffic. This system is designed according to a set of specifications. The Subset-076 is part of this set of specifications, which are the official tests to be run to certify the ERTMS On Board Unit, these being the tests executed at CEDEX RIL.

Hitachi and CEDEX signed in three different contracts for performing the tests between 2017 and 2019, in a feedback process that allowed Hitachi, on one side, to debug their equipment, and, on the other, LIF to do the same with the tests specification. Finally, the tests that were executed in two different periods of time in 2019 resulted in the production of two official reports by CEDEX. These reports include the results of all the tests undertaken, as well as their analysis, which were done by the ERTMS experts at LIF. The reports were sent to the company (Hitachi), in order for it to get the official certificate, which will be issued by CERTIFIER, the French certification organism.

It's expected that the certified equipment from Hitachi will be installed and operate in the trains that will run in the Swiss Bale-Interlaken line (BL3 Level 1 line), as well as in the Paris-Amsterdam line and in the LGVEE high-speed lines Paris-Strasbourg, BPL and SEA. In the foreseeable future, as the tested system is part of the so-called "bi-standard", together with the TVM, which is the system used in French high-speed lines, this will be the equipment installed in all the TGVs running throughout the neighbor country.



Eurobalise and Euroloop antenna.

Carry Load Study of an Industrial Building Structure at San Fernando de Henares (Madrid)



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The Infrastructures and Cultural Equipment Management, an autonomous institution of the Ministry of Culture and Sport, commissioned the Central Laboratory for Structures and Materials a study about the carry load structure of an industrial warehouse building located at San Fernando de Henares (Madrid).



External view of the building.

The studied industrial building was built around 1975 as General Store of Galerías Preciados, designed by the architects José Antonio Corrales Gutiérrez, Ramón Vázquez Molezún and Rafael Olalquiaga Soriano. Its structure, floors and columns were made of reinforced concrete. The roof was erected with precast concrete beams built by Pacadar, due to a change from the initial project. By 1995 the building was unoccupied. Currently, the building is still empty, without any use. Near the main warehouse is the smaller original office building, which is used nowadays for the National High Court.

Built in 1975 as Galerías Preciados general warehouse

Projected by Corrales, Vázquez y Olalquiaga

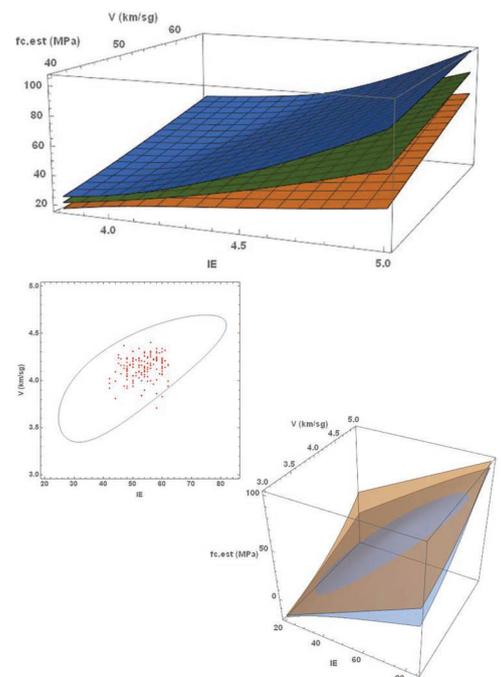
Carry load structural study

The warehouse building is located between the towns of San Fernando de Henares and Torrejón de Ardoz. It has a quadrangular plant, 200 m side length. It has two symmetrical "central internal courtyards", diaphanous from the basement to the roof, and separated from each other by a central floor body. There are two other floor bodies at the opposite side of each internal courtyard.

There was a metallic shelving system that filled the internal courtyards, where the goods were stored. The floor bodies next to the courtyards were used to get to the shelves.

The first inspections of the building were made in 2009. At the time, significant damage was detected in the roof waterproofing system. That situation helped the degradation development in the concrete structure that was detected in the 2019 study.

The study focused on determining the carry load capacity of the floors structure by destructive and non-destructive testing, and on analysing the quality and strength of the concrete. The concrete structure damage and the definition of reparation were also studied.



Adjust, variability limits, and scope of validity graphics for concrete columns strength correlation.

Testing for Structural Steel Certification



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EAE Structural Steel Code is the current technical regulation in the field of steel structures, both in civil engineering and building. Materials that make up the structural elements are regulated by the different parts of the UNE-EN 10025 standard. They're non-alloy-hot-rolled steels or steels with special characteristics. Structural products are full section profiles and sheets, hot finished hollow section profiles, and cold formed hollow section or open section profiles.



Profile projectors.



Charpy Pendulum.

CEDEX is the verification laboratory of the Technical Committee for the Certification of "Profiles, bars and plates of hot rolled steel for structural applications" (CTC-046), which aims to certify structural profiles, shoring profiles, structural plates and hot rolled steel bars and profiles, and the distribution service for these products. This Committee manages the AENOR certification system for structural steel products, the secretary of which is CalSider-Siderurgical Quality. The work of the Committee regarding the concession or the holding of the AENOR product certificate requested by a manufacturer, either national or international, and in particular, the analysis and laboratory tests required for the certification of a product, is driven by N mark regulations.

The Central Laboratory for Structures and Materials is accredited by ENAC in the Quality Management System, under the standard UNE-EN ISO/IEC 17025, for carrying out a large number of tests, including all those affecting structural steel. The ENAC accreditation guarantees the quality assurance of the test results, implementing further activities above the testing methods, such as the regular equipment calibration, the internal validation and verification of the working methods, the interlaboratory result comparisons, or the accuracy and uncertainty research related to the results of the direct and indirect magnitudes obtained through the tests.

Laboratory facilities for the certification of the structural steel products

- Equipment to measure geometric, dimensional and weight characteristics: profile projectors, calipers, balances, flexometers, squares, micrometers, goniometers, measuring wedges, etc.
- Equipment to determine chemical composition: spark atomic emission spectrophotometer, infrared analyser and thermal conductivity analyser
- Tensile test machines of variable load capacity ranges, strain gauges with measuring bases of various ranges, markers and meters of elongation and constriction, and control devices equipped with specific software
- Charpy pendulum with thermostatic bath for cooling specimens up to -50 °C

Survey of Performance Indicators in Highway Contracts



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The Directorate-General of Roads has commissioned CEDEX to verify the suitability of the indicator measurement data provided by the concessionaires of a number of highways maintenance contracts, and to verify the applicable factors, for the period 2018-2021.

The Central Laboratory for Structures and Materials is responsible for verifying and checking the indicators listed in worksheet nº 5 "Retroreflection of road markings", and nº 6 "Retroreflection of road vertical signals", of the aforementioned commission.

In sheet nº 5, CEDEX checks the quality of the retroreflected luminance coefficient values of all road markings measured by each concessionaire. It's done by studying the related data and performing comparative measurements in sections selected by CEDEX, checking the calculation of the correction and penalty factors associated with the indicator. Checking and reporting are carried out in two annual measurements.

In sheet nº 6, the quality of the retroreflection values of all vertical signals of each section of concession is checked, by studying the data provided by the concessionaires and auscultating certain sections. Verifying the proposed factors and issuing the reports are carried out in one annual measurement.

The commission provides, in the case of significant differences, the performance of analysis taking into account new measurements and / or claims submitted by the concessionaire. The work of the Central Laboratory includes a complete annual measurement of a section of concession, selected in accordance with the Directorate-General of Roads, for each indicator.

Highways studied: 11 (2,092 km)

Road sections auscultated by CEDEX: 132 km

Complete sections of highways measured by CEDEX: 2 (306 km)
Reports issued: 38

Analysis: retroreflected luminance, coefficient of road markings and retroreflection of vertical signals

Measuring retroreflection of vertical signals in highway A2, section 4.



Study on Concrete of Tranco de Beas Dam

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The study of the leaching process in the Tranco de Beas dam due to the presence of pure water in contact with concrete has been completed in 2019. This report has been commissioned by the Guadalquivir Hydrographic Confederation in Jaén. The study has been carried out by the Area of Material Science of the Central Laboratory for Structures and Materials.

Large accumulations of calcium carbonate deposits were observed in the dam, mainly in galleries and wells. Eight concrete cores were extracted from the dam in order to study the concrete properties. The tests carried out have proved the presence of a leaching process in the cement paste. Portlandite is dissolved and moves through the pores of the concrete, reaching the surface of galleries and the drainage system of the dam. Portlandite has precipitated in these elements in the form of huge carbonate crusts.

The research has been focused in three aspects: to quantify the amount of portlandite that can be still leached from concrete, factors influencing the leaching process and the future behavior of concrete. For that purpose, accelerated permeability tests have been carried out on concrete cores. Moreover, pH, swept solids and dry residue have been measured in permeated water.

As a conclusion, in the actual moment portlandite lost value has been estimated up to 41% of the total amount. This is the maximum lost measured at the bottom of the dam, owing to the high water pressure together with a high clinker content at that point. The leaching of concrete produces also a slight increase of porosity, but not enough to affect other concrete properties as permeability and strength, according to the results of tests.

Reservoir water is not aggressive and the origin of the portlandite leaching is the high permeability of the concrete due to the poor batching. A binder of sand-cement (mix of clinker and calcite filler) and a high water cement ratio was used. Moreover, frequent compacting defects have been also observed in the concrete.

The results obtained in this research show that concrete will keep leaching portlandite in the future, although the dissolution rate will decrease with time. Thus, the formation of carbonate crusts will continue, but more slowly as time goes on.



Carbonate crusts in a well.

-The Tranco de Beas Dam was finished in 1934

- It's a concrete gravity dam, with curved plan (150 m ratio) and triangular profile (slope of 0.75 and 0.03)

- It's 93 m high from foundation. The crest is 166 m long and 5 m wide

- It has 4 levels of longitudinal galleries

Downstream slope, Tranco de Beas dam.



Practical Guide for the Inspection and Monitoring of Polymeric Geosynthetic Barriers Used in the Waterproofing of Reservoirs



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The Directorate-General for Water and CEDEX have signed both a collaboration agreement and a program defining the lines of work to be carried out by CEDEX in relation to research, and development of hydraulic resources and infrastructures.



Sierra de la Espada reservoir. Murcia.



Valle Molina reservoir. Tenerife Island.

Document: practical guide for the inspection and monitoring of polymeric geosynthetic barriers.

Participants:

- Directorate-General for Water
- Central and Autonomous Administrations
- Geosynthetic manufacturers and installation companies

Content: inspection procedures and practical criteria to assess the state of geosynthetic barriers

The Area of Materials of the Central Laboratory for Structures and Materials has been designated to carry out the line of work defined as "Inspection and monitoring of the state of conservation of synthetic geomembranes used in waterproofing of reservoirs in order to verify their validity or to determine the need for their replacement. Preparation of guides and technical recommendations related to the waterproofing of reservoirs".

The objective is the elaboration of a practical guide for the inspection and monitoring of polymeric geosynthetic barriers used in the waterproofing of reservoirs. The aim is to define criteria for the inspection and monitoring of the waterproofing system of the reservoirs, in order to know their condition and to carry out actions such as repairs, replacements and even re-waterproofing of the geosynthetic barrier.

To carry out this task more effectively, two groups have been formed with the participation of public and private

entities: a Working Group, in charge of drafting the guide, and a Supervisory Group, whose objective is to direct and supervise the former's work.

In September, the first meeting was held at the Central Laboratory for Structures and Materials, at which the two groups were constituted with the participation of representatives of organizations from the Central and Autonomous Administrations, as well as companies manufacturing geosynthetics.

On November 6, the first meeting of the Working Group was held to define the objectives, methodology to be followed, and the drafting of the guide.

As a result of the first work meetings, the experience in monitoring polymeric geosynthetic barriers by manufacturing companies and public bodies dedicated to the management and exploitation of reservoirs has been reflected in a first document.

DRAINAGE Project: Towards an Integral Flood Risk Management



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“DRAINAGE: Design of a methodology to increase flood resilience compatible with improved status of water bodies and sustainable management of water resources”, is a project financed by the Spanish State Research Agency (AEI) in the 2017’s calling of the National Research, Develop and Innovation (RDI) Program aimed at Society’s Challenges. It was presented in the form of coordinated projects, being led by the University of Castilla-La Mancha (UCLM), and taking part of it both CEDEX and the Spanish Geological Survey (IGME).



Demonstrative capacity of the project

Multidisciplinary approach
Study area: Duero River, between Toro and Zamora (63 km)

Flood mitigation processes

In collaboration with the University of Castilla-La Mancha (UCLM) and the Spanish Geological Survey (IGME)

Aerial photo of fluvial bars in a meandering section of the Duero River (June 2019).

The time running from 1 January 2018 to 31 December 2020 has been a developing period. The Centre for Studies of Applied Techniques (CETA) leads subproject 2: “Analysis of **advanced methodologies** to improve flood resilience and the **eco-hydrogeomorphological quality** of water bodies”. This subproject aims, on the one hand, to determine accurately the ecological status (hydromorphological, physical-chemical and biological) of the water body under study, and, on the other, to advance solutions based on **natural water retention measures (NWRM)** to achieve three objectives: i) improve flood resilience; ii) improve the quality of water bodies; and iii), move towards a more sustainable management of water resources.

To this end, innovative methodologies have been used -for example, **air drones** for topographic surveys-, in order to understand more precisely how river ecosystems behave in flood episodes. To test these methodologies, the main study area of the project has been located on the Duero River, between the municipalities of Toro and Zamora.

This project has the backing of Promoter-Observer Entities (EPOs), such as the Directorate-General for Water, the Duero River Basin Authority, the Civil Protection Agency of Castilla y León or the Directorate-General of Cultural Heritage of Castilla y León. Also, the project keeps a website (<http://drainage.cedex.es/>), on which updated information can be consulted.

The Environmental Radioactivity Monitoring Network of Spanish Inland and Coastal Waters



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CEDEX carries out environmental radioactivity surveillance of Spanish inland and coastal waters on behalf of the Nuclear Safety Council (CSN). This program is part of the national environmental radiological surveillance network developed by the CSN with different organizations to comply with Articles 35 and 36 of the Euratom Treaty. These articles specify that each Member State shall establish the facilities necessary to carry out continuous monitoring of the level of radioactivity in the air, water and soil, and that the authorities shall communicate information on the checks referred to in Article 35 to the Commission.



Sampling locations of the environmental radioactivity monitoring network of Spanish inland and coastal waters.

The information drawn from the different analytical determinations performed by the Isotope Applications Laboratory for the measurement of water radioactivity (gross alpha, gross beta, direct tritium, electrolytic tritium enrichment and gamma spectrometry), is stored in a database with Microsoft Access® that centralizes all the information of the samples.

The determination of very low levels of radioactivity requires specific sample preparation techniques, the use of highly sophisticated radiation detectors with highly stable electronic chains, and reliable calculation techniques.

Types of measurements and equipments

- The types of measurements are: gross alpha, gross beta and residual beta activities. Tritium determination, cesium-137, and artificial gamma emitters

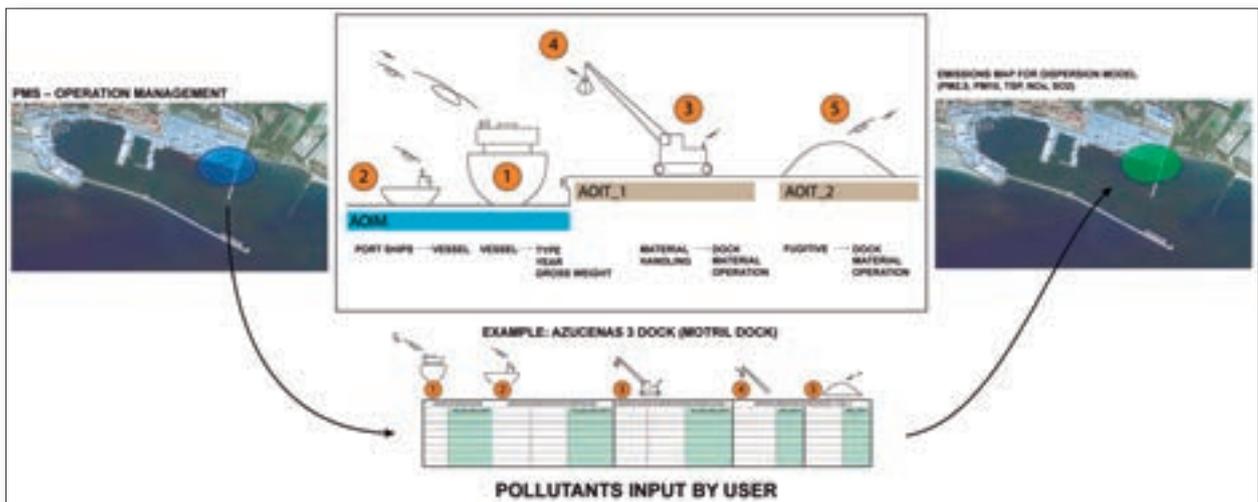
- The equipments used are: ZnS(Ag) solid scintillation counter, liquid scintillation spectrometry, gas-flow proportional counter, and gamma spectrometry

Operational Modeling of Dispersion of Air Pollutant Emissions Based on Samoa

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CEDEX, in collaboration with Puertos del Estado (PE), the wind engineering company Oritia & Boreas and 16 Port Authorities, is working on the implementation of an operational modeling of dispersion of atmospheric pollutants within the SAMOA project in each of the ports managed by the aforementioned authorities.



Decision process diagram of the Port Authority resulting from the dispersion modeling of atmospheric pollutants.

The project begins with the modeling of the physical port environment, which incorporates information on polluting emissions into the atmosphere, both from port operations associated with its activity and from others located in its immediate vicinity for logistical reasons. The atmospheric dispersion model becomes a tool to know in advance how cities close to ports are affected by atmospheric pollution caused by port activities.

The use of these types of models helps to improve port management operations, docking/ maneuvering of ships, and unloading of goods. It's a further advance in the path of improving the efficiency of the port system, thus saving in operating times, which results in a reduction in the consumption of energy-carbon footprint and polluting emissions into the atmosphere of different pollutants such as SO₂, NO_x, PM-10, PM-2,5 (particulate matter), etc. The use of these tools results in the improvement of air quality and, thereby, in the betterment of public health of port cities.

This work is implemented with a survey that is distributed and completed by each Port Authority, and serves as a script to address air pollution problems reported through on-site visits to each port, and the response of environmental authorities, public health and citizens to this reality.

Working group that participates in the project of dispersion of atmospheric pollutants that affect the port environment, based on SAMOA:

- National Port Authorities
- Port Authorities (16 ports participate in this exercise, which includes a visit to the ports and an analysis of responses, contained in a form prepared to the effect, about environmental problems in atmospheric pollution)
- Wind engineering specialist company (Oritia & Boreas)
- CEDEX

Impact of Roads on Pollinators in Different Climate Scenarios



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The Roads and Pollinators project aims to analyze the impacts of roads on pollinators in different Spanish locations. With this objective in mind, a pollinator collector has been designed to emulate insect roadkills by vehicles, instead of the usual systems where pollinators are collected from roadsides.



Pollinator collector installed on the vehicle to carry out the tests.

Pollinator communities are in rapid decline because of the numerous threats they're under (agrochemicals, monocultures, parasites, invasive species), as well as others of enormous magnitude such as climate change and a progressively more extensive network of linear transport infrastructures.

The tests carried out in 2019 to assess the functioning of the insect collector have been successful, offering a series of hypotheses to work on in the coming years regarding the effects of highways on the abundance and richness of pollinator species and, also, on the species composition of their communities.

Sampling units

In rural areas each sampling unit includes a section of about 10 km of motorway and a rural road that runs approximately parallel, at an average distance of more than 300 m. In suburban areas only the motorway is sampled

Localities

The rural landscapes are flat and mosaic, in Leon (A-231), Toledo (A-40) and Valencia (A-7). The suburban motorways, in Madrid, are the eastern axis of the M-30, the exits of the A-3 and A-5, and the complete ring of the M-40



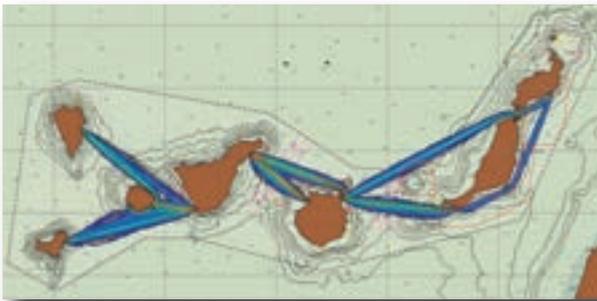
The Roads and Pollinators project evaluates both the roadside effect and the direct run-over of pollinators by vehicles.

Study of the Inter-Island Maritime Traffic With Respect to Collisions Between Ships and Cetaceans in the Canary Islands

Contact: ana.lloret@cedex.es



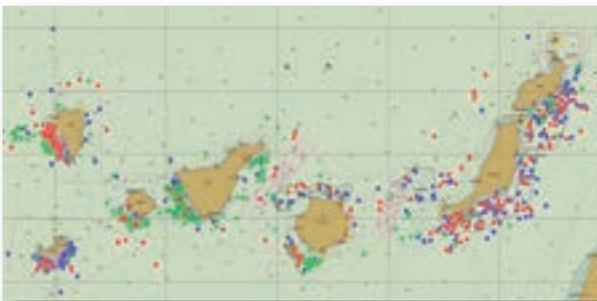
One of the main applications of the historical AIS database compiled by CEDEX consists of maritime traffic studies in Spanish jurisdictional waters. The development of a methodology for processing AIS data, provided by SASEMAR, resulted in a number of projects conducted by CEDEX in 2019. A significant increase in the number of stranded sperm whales in the Canary Islands, where the most common causes of death of these cetaceans are ship collisions, encouraged the Directorate-General for the Coast and Sea to ask CEDEX for commissioning the study.



Traffic density of high-speed ships, km /km².

The geographical scope of the study covers all the extension of the Particularly Sensitive Sea Area (PSSA), designated by IMO in the Canary Islands with a time frame running from May 2018 to April 2019, including more than 130 million of AIS data corresponding to ships devoted to inter-island traffic. Of the 28,000 analysed tracks, 20,000 correspond to high speed vessels, grouped into 23 main routes, characterized by several key statistics giving as a result an average speed over 14 Knots in nearly all cases, estimated as lethal threshold for cetacean collisions.

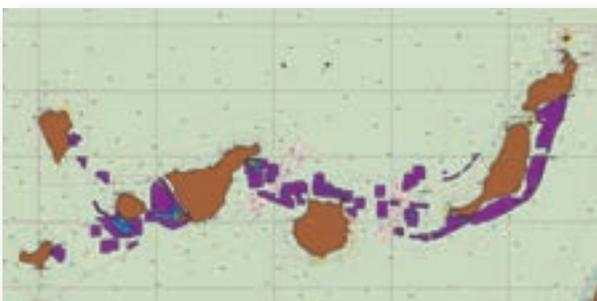
Traffic density maps were produced both for single routes and the full set of them from all the data processed.



Cetaceans occurrences of interest for the study.

Information provided by the Regional Government of the Canary Islands related to cetacean occurrences, particularly about deep diving habits species like sperm whales, to be considered among the most vulnerable to die if ship collisions, has enabled the development of a cetacean exposure map in the PSSA of the Canary Islands.

In the risk assessment of collisions with lethal effects, a 30" grid was used in the approach developed and applied. This methodology was based on the product of these two elements posing the risk: on the one hand, the hazard associated to the density of ships cruising PSSA faster than 14 knots; and, on the other, the exposure assessed projecting the available occurrences over the mesh, considered as an estimation of the vulnerable population density, and taking into account the impact of ships sailing over the mentioned speed.



Map of total risk of collisions for high-speed ships.

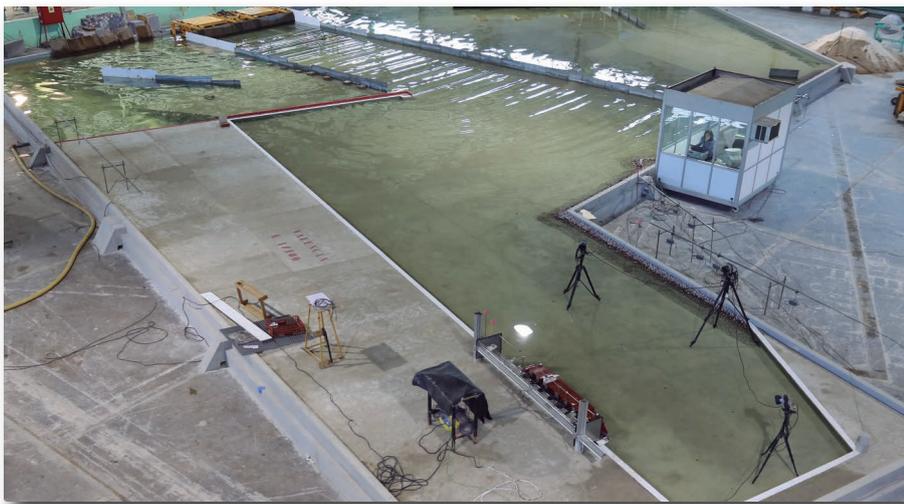
The development of this methodology allows to assess the impact over the total risk from the implementation of specific mitigation measures for collisions, such as route deviation or speed reduction in particular areas.

Study on the New Container Terminal in the North Basin of the Port of Valencia

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One of the main objectives of the Valencia Port Authority (hereinafter APV) is the construction of a container terminal in its North basin, to meet the expected demand for this type of traffic in the medium and long terms. The terminal is designed so that the latest generation of container ships can operate, serving both import and export traffic, and transshipment. In order to achieve the optimal design of the terminal plan configuration, APV and the National Port Authority commissioned CEDEX the following three studies: a numerical model study, a 3D physical model, and a maneuvering simulation of ships.



General view of the model and detail of a moored ship test.

Among the actions planned by APV for the new container terminal in its preliminary study, it proposed the extension of the current dock by 515 m and a counterdike, so as to improve its shelter conditions. In order to optimize the breakwater length, APV put forward several alternatives, consisting of different lengths of the breakwater extension, and the possible need for the counterdike.

The objective of the numerical model was to analyze the wave disturbance inside the basin on two alternatives for the extension of the breakwater (257 m and 172 m, with or without a counterdike), and an additional alternative consisting of "no extension" of the breakwater.

Results of numerical model showed that in no case were not exceeded the inoperative thresholds considered acceptable in accordance with the recommendations of the ROM, so it was considered that the expansion of the breakwater or the construction of the counterdike was not necessary.

By means of the physical model, the behavior of the solution "without extension" of the breakwater was verified, and wave disturbance and docked ships tests were undertaken. In wave disturbance tests, wave conditions were measured inside and

in the entrance to the North basin. In the tests of docked ships, the behavior of a 218 m length container ship, deemed as medium size, moored in two berth positions of the container wharf located at its ends, was analyzed. The half load condition was considered, and the starboard mooring system was arranged in both berth positions.

The results related to the operation of the container dock, resulting from both tests –wave disturbance and docked ships-, indicated a very high degree of operationability, both from the point of view of wave disturbance, and the behavior of the container ship in the two berths. Based on the global results of the study, it was possible to conclude that it was neither necessary the extension of the breakwater, nor providing a counterdike for the protection of the North basin.

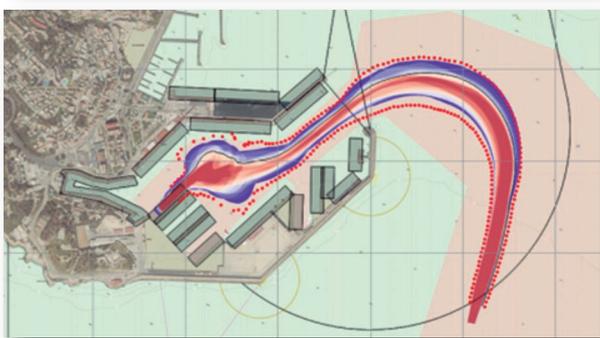
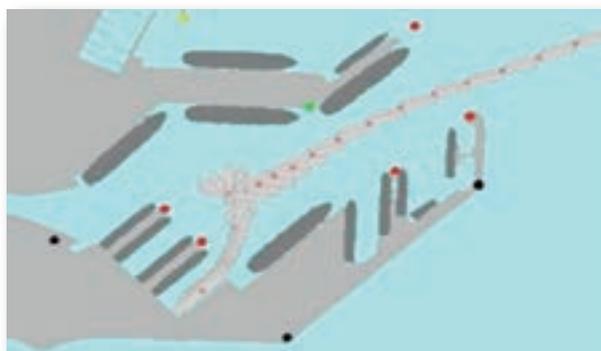
The ship maneuvering simulation study is currently being carried out in real time, which will also serve to verify the suitability of this solution from the point of view of navigability.

Ship Maneuver and Operational Study for a New Configuration of the SW Basin of the Port of Palma de Mallorca

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The SW basin of the port of Palma de Mallorca focuses its activity on the traffic of ferries or regular lines (passengers, general merchandise), in addition to having an important occupation of tourist cruises. Currently, there is a significant simultaneity in the basin in the arrivals of these ships in a time slot very early in the morning, with the consequent concentration of port traffic. To provide this basin with a new configuration, the Balears Islands Port Authority (APB), and the National Port Authority (PE), commissioned the Centre for Studies on Ports and Coasts (CEPYC), of CEDEX, to carry out a simulation study of ship maneuvering, and an operational study of the new configuration of the basin.



The objective of the study was to analyze the maneuverability of the ships, as well as the safety and maritime operational conditions to verify the design of the new configuration of the SW Basin proposed by the APB.

By means of the simulation study of maneuvers in real time, the feasibility and safety of the access, turn, approach, docking, undocking, and departure maneuvers have been analyzed for each of the type of ships indicated by the APB, accessing or leaving their corresponding berths, in the three configuration alternatives put forward by APB.

The study has made it possible to determine the wave-wind-tide, and current combinations that constitute the operational access/exit limits for each type ship in relation to its berths.

In addition, a statistical study of the area occupied by the ships during the simulations has been conducted in order to detect what the critical points were in each maneuver.

The study was executed in real-time ship navigation, and with the maneuvering simulation system POLARIS, available at CEPYC.

Prior to carrying out these studies, CEPYC's Department for Climate and Port Studies had undertaken a maritime climate study, so as to establish the wave and wind conditions to be considered in maneuvering simulations.

Likewise, an operation study of maritime traffic is underway, including an operations scheduling protocol, in order to analyze the operational conditions of the proposed alternatives. In so doing, it's been taken into account the sensitive hourly simultaneity of the stopovers based on the number and characteristics of the ships, and the meteorological conditions that may arise, characterizing the current traffic based on AIS data, and the likely one on the horizon of the master plan for the port of Palma regarding the ships under study.

Agitation and Current Numerical Study in Melilla Harbour Enlargement

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This study was conducted at the request of the Port Authority of Melilla (APM), and the National Port Authority (PE), with the aim of analysing, in numerical model, the variation with respect to the current situation of the wave disturbance of Melilla harbour in summer and autumn periods. The study should considering the future "ecological channel" of the expansion, the areas of the East and North docks of Noray harbour and the east coast near the Galápagos cove.

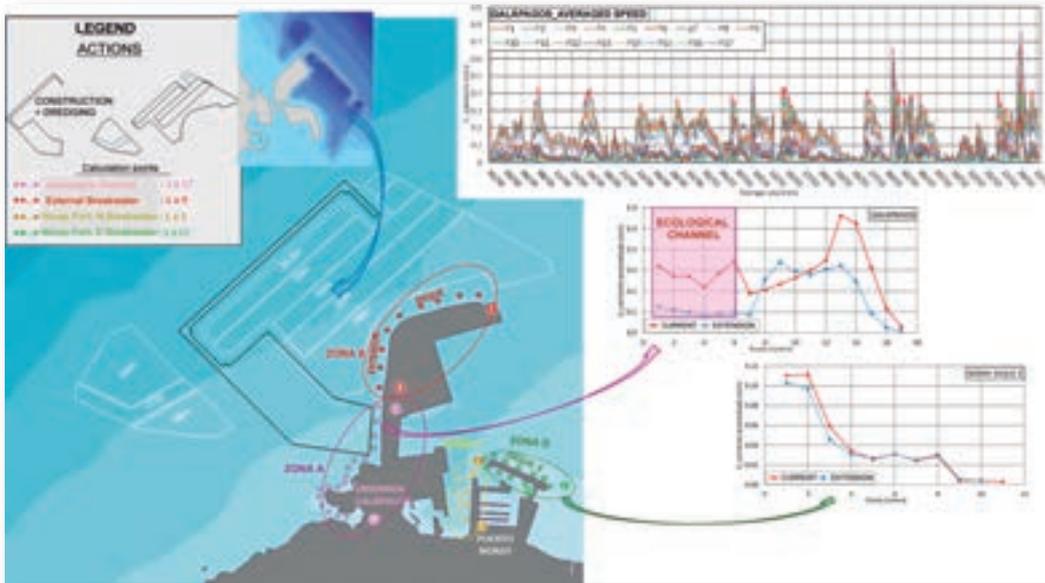


Figure 1.
Test configurations, control points and current results.

For bottom reproduction in the numerical propagation area the bathymetric data supplied by the APM, and those contained in the nautical charts of the Instituto Hidrográfico de la Marina (IHM) was used. For numerical reproduction of wave climatic characteristics in the two season's periods, the historical series of synthetic waves of the point SIMAR 2049064 of PE was employed. The corresponding to tide and current levels was supplied by the prediction system of and reanalysis of climate parameters of the NOAA Global Forecast System Reanalysis (CFSR NCEP).

The "MDSL" elliptical wave propagation model, developed at CEDEX, was used for the wave disturbance study. Simulation of the currents associated with wave breakage, wind and tide was carried out with the nested numerical model "MIKE3/FM", from the Danish Hydraulic Institute (DHI).

Wave disturbance numerical simulations were calibrated with the results obtained in the agitation tests carried out in physical model in 2018 at the Centre for Studies on Ports and Coasts.

From the results obtained at the control points proposed by the APM (Figure 1), the following behaviour can be inferred:

- Wave disturbance levels in the future "ecological channel" are of the same order as those currently existing in the East and North docks of Noray harbour.
- Tide currents on Melilla coast in both season's periods are irrelevant, and those generated by the breakage waves depend on their direction in relation with the coast and their wave heights magnitude. This dependence determines how high waves coming from the fourth quadrant are irrelevant for the currents in the project area.
- The intensities of the currents in the control points located in the future "ecological channel" (points 1 to 5) show a reduction with respect to the current configuration, being its magnitude similar to those obtained in the North dock of Noray harbour.

Course on Coastal Engineering and Marine Environment

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In 2019, the Centre for Studies on Ports and Coasts hosted three editions of the *Course on Coastal Engineering and Marine Environment*, organized by order of the Directorate-General of the Coast and Sea (DGCM) with the aim of training its technicians, both of central and peripheral services, in coastal engineering and environmental aspects.



Figure 1. View of the classroom where the course was held.

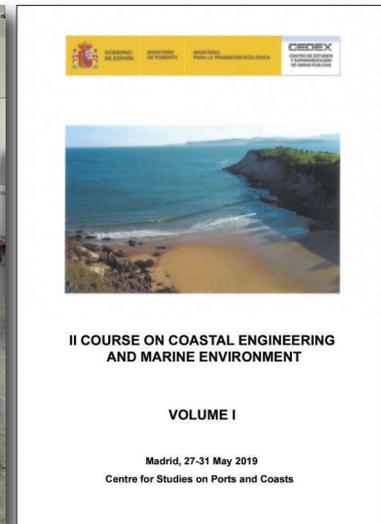


Figure 2. Course manual.

The three editions of the course run for five days, with a total of 36 hours distributed in five modules and fourteen lessons, all of them taught by CEDEX staff, at CEPYC headquarters.

The response to the course was very positive since its calling, receiving more than 70 requests which made it necessary to augment the number of editions of the course up to three (initially only two were planned). In addition to DGCM staff, the course was extended to CEPYC staff, of which 10 people took part.

The three editions of the course were held on 25-29 March, 27-31 May, and 23-27 September.

Along with the face-to-face classes of the course (figure 1), extensive documentation was provided to the students in two volumes (figure 2), which is currently being edited in the form of a book for publication by CEDEX.

The evaluation of the course, both by assistants and teaching staff, was very positive. For part of the

students, who were asked on various aspects of the course (general level of the course, teacher level, agenda, documentation, organization and facilities, etc.), there was a very high mark.

With regard to the students, the teaching staff and the organizing team of CEDEX as a whole, the CEDEX-DGCM “win-win” benefit obtained from coming face-to-face with DGCM technicians is to favour the creation of a network that will make those ones get acquainted with CEDEX. This, together with CEPYC’s strengths in the field of Coastal Engineering and Marine Environment, and its availability for the resolution of problems, will enhance the skills of, among others, the participants from the aforementioned DGCM.

Support for Water Regulation Development in Latin America

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The Centre for Hydrographic Studies of CEDEX is providing technical assistance to the Water and Sanitation Cooperation Fund (FCAS) in a regional strategy for the development and improvement of sectorial regulations related to sanitation and wastewater treatment.



*Open sewer
(Nicaragua).*

*Wastewater treatment
plant (El Salvador).*



Since the collaboration with FCAS began in 2012, CEDEX has conducted several actions in water regulation development. The proposals for use and effluent discharge fees prepared for El Salvador or the assistance to Honduras in the development of the Special Regulations for River Basin Authorities could be highlighted as examples.

Although water regulation development in the region is very uneven, there are common issues that are of particular concern since they will determine the path to follow to achieve the Sustainable Development Goals (SDGs), and especially the 6th one. Many Latin American countries have regulations for effluent discharge that hinder rather than promote the adequate development of sanitation and wastewater treatment, either due to excessive exigency or quite the contrary. In addition, many countries also have a lack of regulations governing the wastewater reuse or the disposal of sewage sludge. In this framework, the FCAS with the assistance of CEDEX has initiated a regional strategy to support water regulations review and development.

As first steps, this initiative was announced at the Conference of Ibero-American Water Directors (CODIA) held in Guatemala. At the same time, contacts with different countries were established, requesting sectorial regulations, which were analysed to identify problems and shortcomings, and later the initiative was presented at the LATINOSAN 19 Conference held in Costa Rica, where the main conclusions of the regulation review were also presented. As a result of these actions, requests for support have been received from several countries, such as Cuba, Haiti, Colombia, El Salvador and Paraguay.

The collaboration with Cuba began in 2019, carrying out an analysis of their effluent discharge regulations. This study has been taken as a reference by Cuban institutions for the revision of the named regulations. Besides, two content proposals have been made for the regulations for the wastewater reuse and for the disposal of sewage sludge, which have served to start the discussion on its development.

As next steps, apart from starting bilateral collaboration with the other countries, it's planned to organize regional workshops, with the participation of international experts, to help the authorities make decisions for the revision of their water regulations.

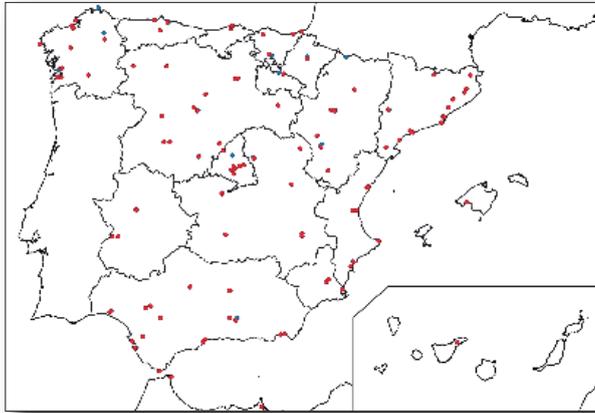
It should be pointed out that in addition to the activities for the FCAS, CEDEX collaborates with Argentina in the proposal of a wastewater reuse regulation and, probably from next year, in the revision of the effluent discharge regulations. With the work of these years and this new regional initiative, CEDEX begins to play a notorious role in the water regulation development in Latin America, similar to the one that CEDEX has played in Spain for a long time.

Maximum Rainfall Maps and IDF Curves

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The Centre for Hydrographic Studies is currently updating maximum daily rainfall maps and intensity duration frequency (IDF) curves. These works have their antecedents in “Maximum daily rainfall in Peninsular Spain” (CEDEX, 1993), and in the IDF curves “Regulation 5.2-IC of Surface Drainage of the Highway Instruction”.



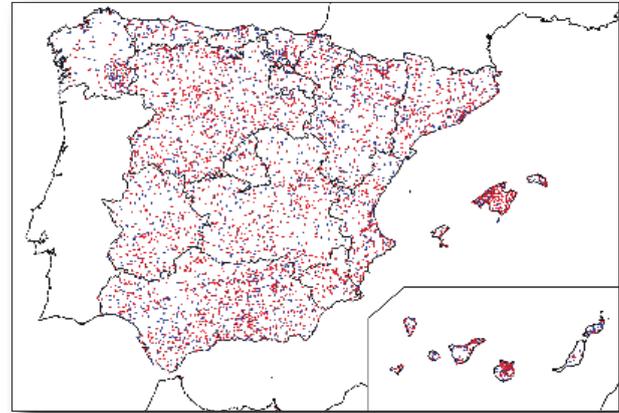
AEMET's pluviographs.

The Centre for Hydrographic Studies has, among its main tasks, the national scale characterization of hydrological variables, such as maximum daily rainfall and relations between maximum intensities and durations for different probabilities. These studies are used as the basis of flood hydrological studies in flood prone areas analysis and road drainage studies. Due to the extended period of time elapsed since current available works were concluded, the updating of these studies is being undertaken. For this purpose, current available rainfall information has been gathered and data time-series treated in order to complete and debug information. Regional statistical time-series analysis is currently being developed in order to obtain the frequency laws of the variables. Starting data comes mainly from State Meteorological Agency's monitoring network (AEMET) from which 4249 rain gauges and 126 pluviographs have been selected.

Available maximum rainfall and intensity data has been reviewed and analysed in terms of:

Pluviometric starting data:

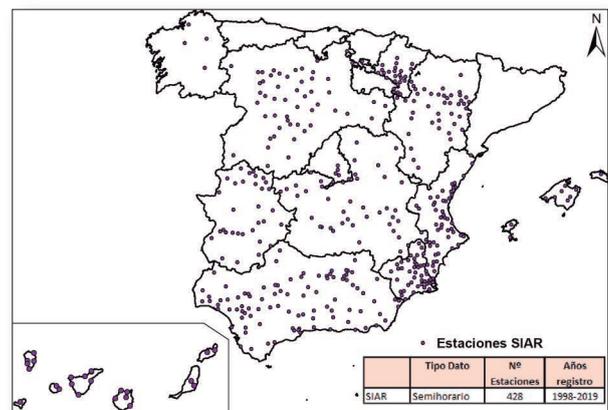
- AEMET's rain gauge stations: monthly maximum daily rainfall data time-series
- AEMET's pluviographs: daily rainfall time-series for the following durations:
 - Maximum rainfall in 10, 20, 30, 60 minutes, and 2, 6, 12 hours
 - Hourly rainfall (from 0 to 24 h)



AEMET's rain gauges.

- Removing nearby data stations with redundant information.
- Starting time-series gap filling and annual maximum time-series preparation.
- Abnormally high values (outliers) detection.
- Trend analysis in order to detect systematic errors in time-series.

Equally, rainfall data from other sources, such as autonomous communities' own monitoring networks and Agroclimatic Information System for Irrigation (SIAR), have also been gathered.



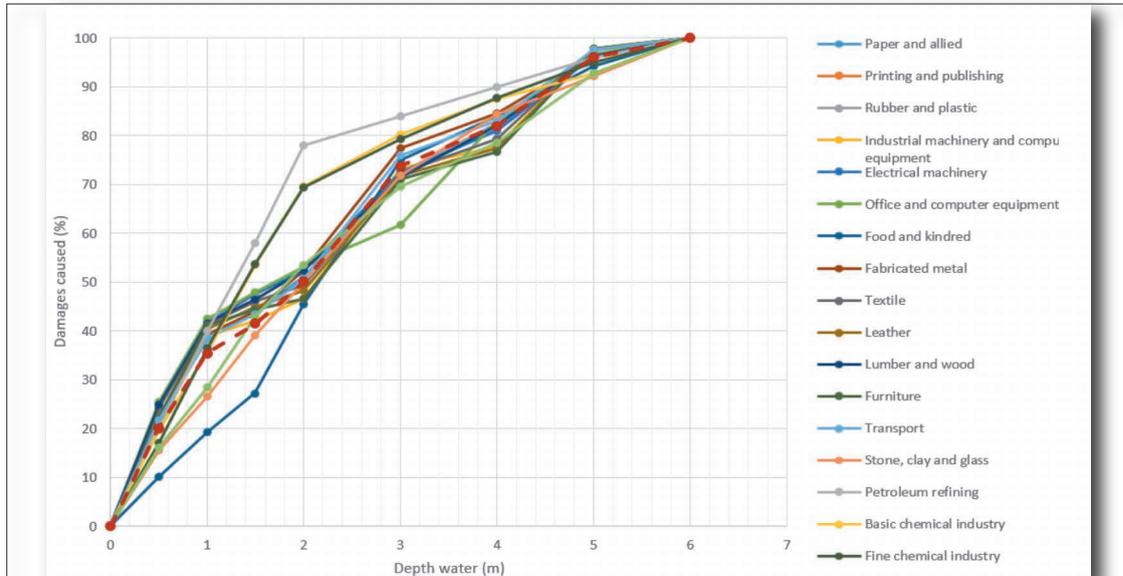
SIAR monitoring network.

Methodological Guide for the Cost-Benefit Analysis of Flood Defence. Structural Measures



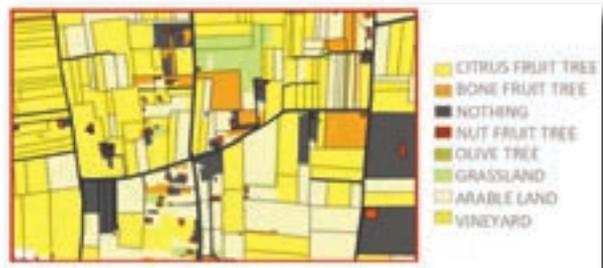
Contact: antonio.jimenez@cedex.es

The Centre for Hydrographic Studies is developing a guide which includes recommendations and methodologies to tackle the cost/benefit analysis (CBA) of flood defence structural measures.



Damage functions by type of industrial activities X-axis: depth water reached by the flood (m)
Y-axis: damages caused (% of the total value).

- Easing the implementation of the structural measures of the Flood Risk Management Plans
- Providing recommendations and methodologies for the estimation of flood damages in the different types of land use: urban (residential, commercial, offices, service buildings, public services, vehicles, etc.), industrial, infrastructures, agriculture and livestock



Case study in Jávea. Image above: damaged crops by the flood of Jávea in October 2007.

This work consists of the development of a guide which contributes to ease the application of a CBA of flood defence structural measures, as a tool for establishing its economic profitability, within the context of the Flood Risk Management Plan. The methodologies to be applied for estimation of flood damages is one of the main aspects on which this guide focuses, since the feasibility or profitability studies of flood defence measures requires in order to determine the benefits, the estimation of the avoided damage thanks to the measures, as well as its economic assessment.

The guide consists of a memory that includes the following paragraphs:

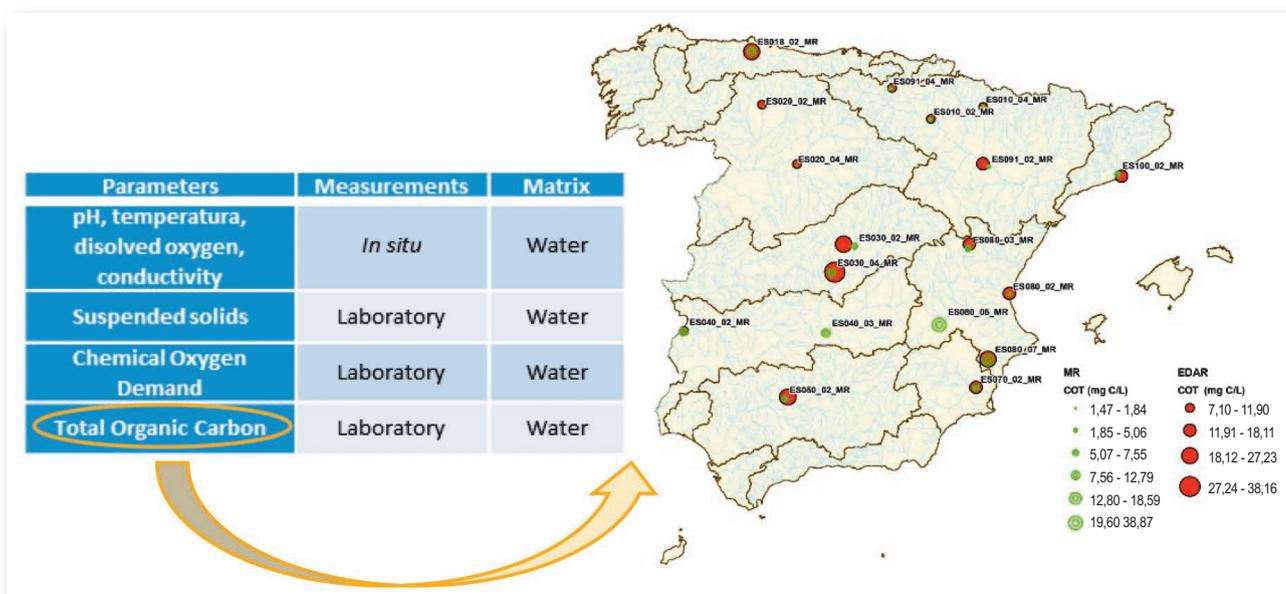
- Description of fundamentals of the CBA and the different steps to take for carrying it out.
 - Methodological proposal for the quantification and economic assessment of the flood damages.
- Besides, the guide includes some annexes with:
- Collection and analysis of flood damage estimation methodologies.
 - Application of the flood damage estimation proposed methodologies to flood event that took place in Jávea in 2007.

Monitoring Watch List Compounds

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The Centre for Hydrographic Studies provides technical support for the determination of emerging substances included in the research control programme defined in RD 817/2015 and Water Framework Directive.



Analysed physicochemical parameters at control points. Results of total organic carbon obtained from different places.

In regard to emerging contaminants, Directive 2013/39/EU of 12 August 2013, amending Directives 2000/60/EC and 2008/105/EC concerning priority substances in the field of water policy, establishes a Watch List (WL) of substances for which monitoring data are to be gathered for the purpose of supporting future revisions of the priority substances list.

Substances in the watch list are regulated in Article 25 and Annex IV, Paragraph c, of RD 817/2015 of 11 September 2015, which sets the criteria for monitoring and evaluating the status of surface waters and environmental quality standards. The substances in the watch list are to be selected from among those for which the information available indicating they may pose a significant risk to or via the aquatic environment, but for which monitoring data are insufficient to come to a conclusion on the actual risk posed.

Substances considered for being included in the watch list are those which are highly toxic substances, used in many Member States and discharged to the aquatic

- Technical support for the watch list research network
- Analysis of physicochemical parameters, pesticides (8), drugs (7), cosmetics (1) and industrial chemicals (1)
- High-resolution analytical techniques are being applied for carrying out water analysis

environment but they have not been monitored or rarely determined. Therefore, the monitoring of these substances should generate high-quality data on their concentrations in the aquatic environment, fit for the purpose of supporting decisions about the risk assessment that underpin the identification of priority substances.

The analysis of this kind of substances in Spain is carried out for a 4-year period, and samples are collected from 36 control points corresponding to different wastewater treatment plants and their receiving environments, selected by the river basin authorities.

Applied Research on Spillway Channels Aeration in the Hydraulics Laboratory

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Through Emulsiona project, funded of the R+D+Innovation National Plan of the Ministry of Economic Affairs and Digital Transformation, CEDEX has carried out, over the last few years, different studies about the effects of aeration on hydraulic structures. This work, developed in collaboration with the Polytechnic University of Valencia and the Polytechnic University of Cartagena, has led to several publications in international congresses and journals, besides a PhD thesis.



- EMULSIONA project (National Plan of R+D+Innovation)
- Physical model with high dimensions to ensure the result representatively
- Aeration effects on supercritical flows in spillway channels
- Influence of aeration on the energy dissipation in hydraulic jumps

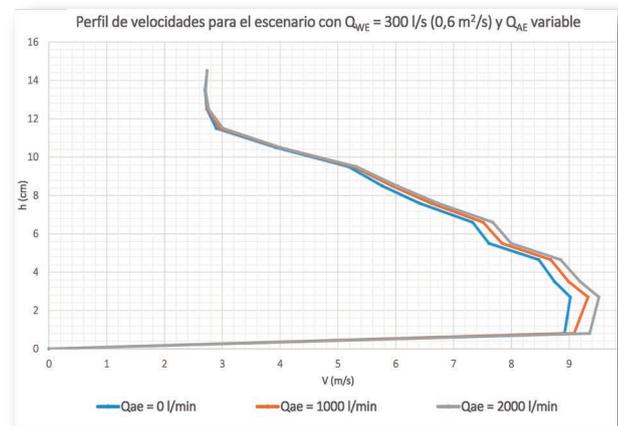
Physical model working during the experimental works.

Results from this research developed in a high dimension model at the Hydraulics Laboratory of the Centre for Hydrographic Studies of CEDEX, show different conclusions that are very representative of the effects of aeration on spillways and the energy dissipation in hydraulic jumps:

- Comparisons using different methods of concentration measurement in high-speed flows, being the conductivity probe the most suitable.
- With the same conditions in the spillway, results show bigger aeration means a flow acceleration and reduction of the border friction.
- Concentration variation does not improve the effects during the hydraulic jump analysis, but generates instability in the dynamic scheme.
- In future works, it would be interesting to know the development and calibration of numerical models for aerated flows, based on the lagrangian code of the SPHERIMENTAL model.

As for the scientist research results of this project, the most representative publications are as follows:

- “Experimental Analysis of the Influence of Aeration in the Energy Dissipation of Supercritical Channel Flows”. (2019) Water ISSN 2073-4441.



Velocity variations results in flows with different concentrations.

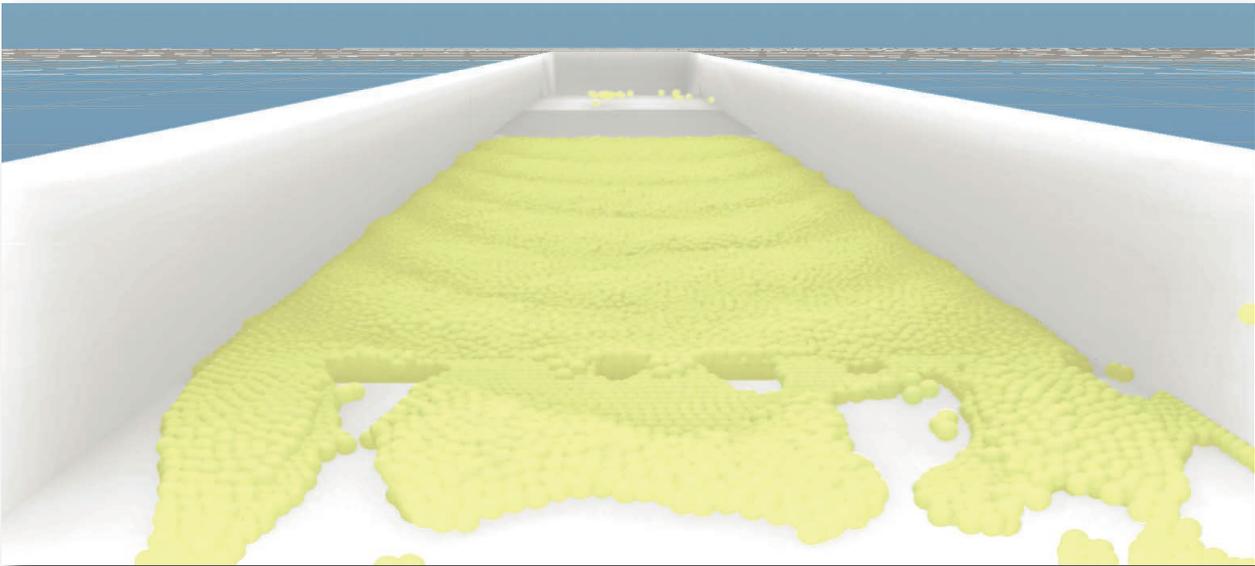
- “Energy Dissipation Structures: Influence of Aeration in Supercritical Flows”, (2018) III International Electronic Conference on Water Sciences (EISSN 2504-3900).
- PhD Thesis: “Influence of flow aeration in supercritical channel flows and in the energy dissipation efficiency in stilling basins”. (2019) Polytechnic University of Madrid. Author: Juan José Rebollo Cillán; Advisors: David López Gómez y Luis Garrote de Marcos.

3D Numerical Modelling. Advances in the Simulation of Two-Phase Flows

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One of the traditional research lines of the Hydraulics Laboratory of the Centre for Hydrographic Studies, is the three-dimensional hydrodynamic simulation of complex hydraulic structures using the SPHERIMENTAL own development model.



3D numerical modelling of bed-load transport. The image only visualizes the sediment grains.

- SPHERIMENTAL is a CEDEX own development model
- The model has multiple applications for three-dimensional hydrodynamic simulation of complex hydraulic structures
- Improvement of the model capabilities for the study of two-phase flows (water-sediment and water-air)

In order to complement the previous physical model study, several alternatives have been numerically analysed to increase the current discharge capacity of Pálmaces Dam spillway so as to reach the safety check flow of 590 m³/s.

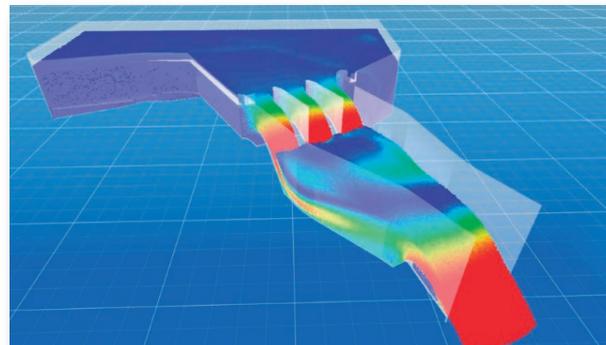
On the other hand, in collaboration with CEDEX's Centre for Studies on Ports and Coasts, SPHERIMENTAL has been used in the study to correct the effect of local erosion at the western end of the second beach of El Sardinero (Santander). Several simulations have been conducted to study the overruns that the incident waves produce on the promenade, and to analyse the influence of the transverse structures arranged to control the beach erosion.

The SPHERIMENTAL model has been improved in its modules for two-phase flows (water-sediment and water-air), which solve the equations of the dynamics between

homogeneous flows (water, sediment or air), considering the rheological equations corresponding to each material (friction in the case of sediment and viscous in the case of fluids).

In the contact between water and sediment, the Shields criterion is used to establish the conditions of the initiation of sediment motion. The interaction between the different water-sediment media allows to reproduce the shapes of a river bed such as ripples and dunes.

The interaction between water and air allows to study transient two-phase flows phenomena in hydraulic structures.



Hydrodynamic study of Pálmaces Dam spillway.

Exhibition: Santo Domingo de la Calzada. The Road Engineer

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Drawing on the engineering works related to the Saint on the Way of St. James, the exhibition was on display from July 2019 to January 2020 at the San Francisco Exhibition Centre in the Riojan town of the same name.



The Rabia Bridge is a passage from the Arga River, very close to the Navarrese town of Zubiri. The name Zubiri means in Basque "the village of the bridge". It is located on the so-called French Way of St. James that gives access to the village from Roncesvalles.

The exhibition, along with other activities such as conferences and concerts, was held on the occasion of the declaration of the Jubilee Year Calceatense, which was added to the celebration of the millennium of the birth of the aforementioned saint.

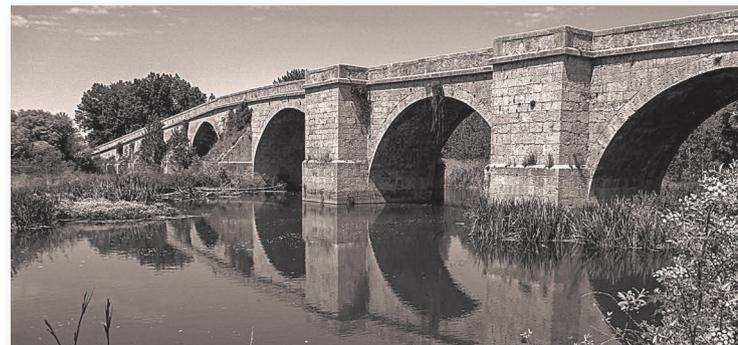
The display was organized by CEHOPU in collaboration with the Bishopric of the Diocese of Calahorra and La Calzada-Logroño, counting on specialists and researchers from the local parish.

The show featured graphic material, as well as models, books, plans, original objects, reproductions or representations at 1:1 scale, catalogue, signage and booklets.

CEHOPU provided the direction and coordination of the exhibition, conjoint curation, direction of assembly and disassembly, and transport of the exhibition components (both new ones and others coming from CEDEX's Collection of History of Public Works). The Bishopric, via the Jubilee Year, facilitated among other elements the design and

materialization of the catalogue of the exhibition, with the collaboration of CEHOPU in the contents.

Finally, the success among both critics and public alike led the organization to extend the exhibition up to January 2020.



The Itero Bridge, also called Paso Itero, Puente Fitero or Ponteroso, located on the Pisuerga River between Itero de la Vega and Itero del Castillo, is one of the longest bridges along the Way of St. James, with eleven arches of seating.





**CENTRES AND
LABORATORIES**



The importance of infrastructure as a support for mobility.

The Centre for Transport Research (CTR/CET) of CEDEX works on a wide range of topics basically related to roads, for these ones are the **infrastructure** on which **transportation** is based, both for people and goods, and, ultimately, make possible the **mobility** throughout the territory, while structuring and giving it cohesion.

In this respect, CET advances the needs and requirements of the infrastructure in regard to the **characterization of the materials** it's made of, to the analysis of the **structural behavior** of the different pavement layers, as well as to the evaluation of the **surface characteristics** of the wearing course.

Moreover, CET addresses the issue of **safety** requirements, for it should not be forgotten that, despite the efforts made to reduce road casualties, just over 1,000 people a year lose their lives on Spanish roads. This entails road administrations striving to make roads as safe as possible.

Likewise, **traffic** moving along roads will be analyzed, since this information allows to know the loads that are acting on them and how they affect pavement deterioration. This will enable an **efficient management** of infrastructure and traffic, all aimed to keep road

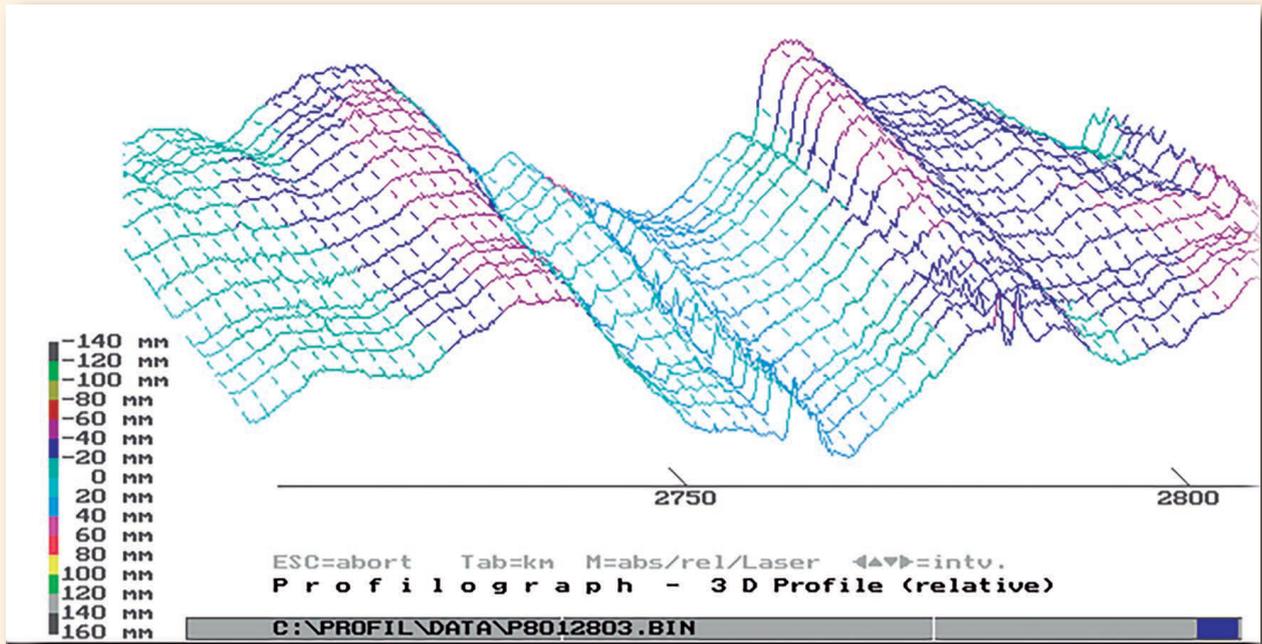
maintenance adapted to both different circumstances and the availability of resources.

It's also important to stress that roads are part of the construction sector, which is one of the largest consumers of **natural resources**, and that road transport is responsible for approximately 90% of total **transport emissions**, which represent around 30% of total greenhouse gas emissions in Spain. Therefore, every action carried out in the field of roads should be inspired and oriented to achieve a significant **reduction in carbon footprint**.

To this end, CET is looking to new initiatives, including the study and application of **new materials obtained from waste**, the creation of a database and a tool to support the conduct of life cycle analysis (LCA) studies in highway projects, the development of a methodology for evaluating the effects of **climate change**, and also research on new possibilities and areas of work linked to a sustainable and connected mobility.

In 2019, the areas CET has been specifically working on have been as follows:

- Monitoring of the **pavement strengthening** of a road in the National Road Network, by means of **sensors**



3D profile of the longitudinal and cross sections of the wearing course of a road.

embedded in the pavement, which allow to know in real time the evolution of pavement damage prior to the execution of that strengthening. All information is processed semi-automatically, providing the road manager with the precise information to determine the pavement condition at all times and the most appropriate maintenance action. The general use of monitoring stations, such as the one placed in this section, would allow the implementation of **predictive maintenance strategies for infrastructures**, which would have an impact on a more efficient maintenance with lower costs throughout their life cycle.

– Characterization, by means of sensors embedded in the infrastructure, of an **experimental road section** built with a cement stabilised soil sub-base course, manufactured with slag from the incineration of **urban solid waste** (on Palma de Mallorca) as aggregate. This work has been carried out for TIRME company, manager of the incinerator for the city of Palma.

– Collaboration in the monitoring of a large number of road sections of the National Road Network, whose maintenance is undertaken through **concession contracts**.

– Organization of an intercomparison test of **friction measurement** devices (SCRIM type), and for the **measurement of longitudinal evenness** (laser profilometer type), which make it possible to check and improve the quality of pavement surveys.

– Support to National Roads Administration in Andalucía with regard to a problem detected in a motorway under

construction, by characterizing the cement stabilised soil used in its construction in order to **detect possible pathologies** in the materials used in its manufacture or in the process of placement on-site.

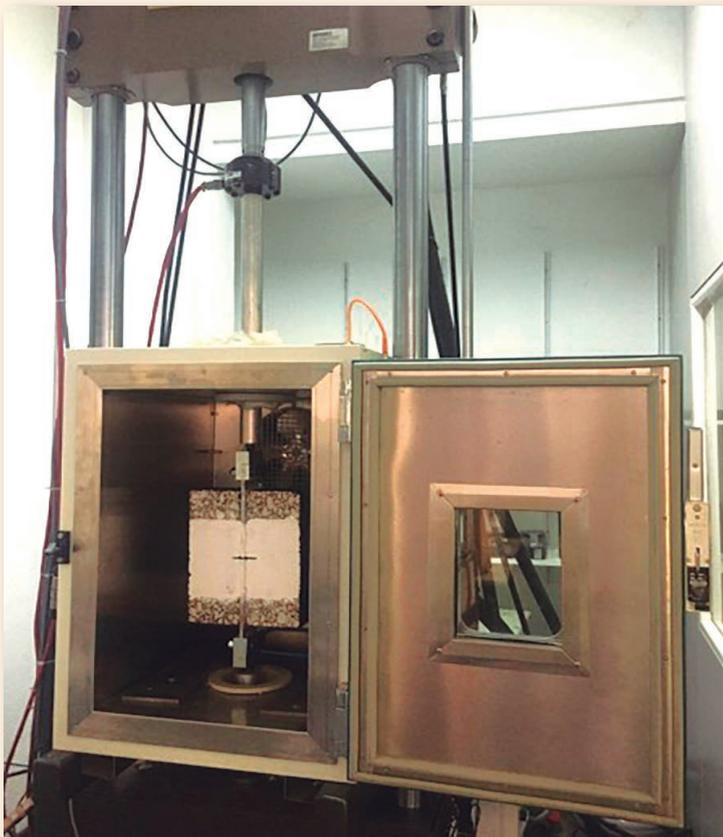
– Experimentation and adjustment of two new **tests to assess different anti-reflective cracking systems**, by simulating a rehabilitated pavement on which the existing crack is reflected towards the surface, due on the one hand to the passage of vehicles and, on the other, to thermal effects. The information drawn from these tests can be very relevant for the design of the rehabilitation of existing pavements in service.

– Coordination of a working group –created by the Directorate-General of Roads of the Ministry for Transports, Mobility and Urban Agenda (MITMA)–, which includes the main actors involved in the **incorporation of crumb rubber** from end-of-life tires (ELT) in the **manufacture of bituminous mixtures** for roads. The objective of this working group has been to prepare the technical documents that will be part of a new Circular Order, which will include the specifications applicable to the crumb rubber, as well as to the binders and to the bituminous mixtures that include this recycled material.

– Review of the documents related to certain worksites where **ELT crumb rubber** has been used in the manufacture of bituminous mixtures. The objective is to accredit the use of this material, so that this information can be incorporated into the **sustainability certificate** of the corresponding project, a document that would provide added merits from an environmental point of view, aiming at future tendering for public works in which valuation



Strategies to reduce the carbon footprint of a road.



criteria based on the reuse and recycling of materials from waste are applied.

– Collaboration with the Road Department of the Polytechnic University of Cataluña in the drafting and editing of the **NLT-383 standard, on Fenix test**, developed by that department, which will be published in mid-2020. This mechanical test allows to easily determine some parameters related to the ductility, creep, toughness and tenacity characteristics of bituminous mixtures, properties that allow **assessing their resistance to cracking**.

– Collaboration with the working group on the interlayer bonding **test for bituminous mixtures (ALEAS, Association of Spanish Laboratories for Asphalt Mixtures Testing)**. By means of this test, a proposal to adopt new values for the current specification contained in **article 531 of the PG-3** (Document of Technical Specifications for Roads and Bridge Works) will be presented to the Directorate-General of Roads. Likewise, on behalf of CEDEX and with the collaboration of that working group, the test procedure described in standard NLT-382/08 will be revised, on which the current values of PG-3 are based.

– Participation in comparative tests, organized by the working group on half warm recycled **bituminous mixtures (30% and 80%) with emulsified asphalt**, promoted by the manufacturers of emulsified asphalt (ATEB). The study covers two methods of compacting the laboratory specimens, and measuring their stiffness and resistance to compression.

– As for the **dynamic weighing of vehicles**, most of the activities in this field have been performed within the framework of the R&D&I **REPARA 2.0 project**, “Development of new techniques and information systems for the sustainable REhabilitation of road pavements”, financed by CDTI (Centre for Technological and Industrial Development). These works are intended to demonstrate the ability of this technique to obtain detailed information on **traffic loads** –without interrupting the traffic flow–, which is of great

Experimentation and adjustment of new tests for the assessment of anti-reflective cracking systems.



Analysis of adaptation and mitigation measures to reduce the impacts of climate change on the roads, including those linked to heavy rainfall.

practical application in road management. Specifically, a **dynamic piezoelectric-type WIM (Weigh-in-motion) system** has been installed in one of the lanes of the A-1 motorway, near El Molar (Madrid).

– Likewise, several activities have been performed within the scope of the study of **road safety** in relation to infrastructure, such as the participation in the Technical Committee TC 3.1 “National Road Safety Policies and Programs” of the **World Road Association (PIARC)**, regarding the definition of national policies for the application of the so-called “**Safe System**”, a concept which, acknowledging that deaths and serious injuries on the road are unacceptable and avoidable, aims to ensure that no user of public highways is to be subjected to an impact in the event of an accident that could cause death or serious injuries, rendering them disabled in the long term.

At CET, we’re aware that **mobility** is changing and that these changes are going to be important in the short term. In addition to conventional vehicles, **autonomous**

and connected vehicles are appearing, with new needs and requirements, and among them, those relying on information and communication technologies stand out. Consequently, it’s necessary to be prepared to manage large amounts of data (**big data**) and pave the way for **artificial intelligence** as one more infrastructure management tool. Furthermore, it’s necessary to have resources to respond to the objective of making **roads resilient, safe, connected, adaptable and self-repairing**, which is an ambitious challenge CET is readying for.



GEOTECHNICAL LABORATORY

Figure 1.
Location of road sections with geotechnical pathologies analysed in 2019.



Within CEDEX, the Geotechnical Laboratory (GL/LG) is the centre specialized in civil engineering activities related to the ground, developing research and technical assistance functions. It participates in the three phases in which any geotechnical action could be divided: 1) phase of investigation of the ground or geotechnical problem, by laboratory, field and auscultation techniques; 2) phase of analysis, through analytical and numerical calculations, on-site or full-scale testing and geotechnical observation; and 3), phase of contribution to the safety of works, by means of geotechnical reports with recommendations on project solutions, correction of pathologies or construction methods for specific works, or through the development of guides and technical manuals. In 2019, the activity has focused mainly on geotechnics of roads, railways and ports and coasts, as well as on environmental and hydraulic works geotechnics. R&D, training and standardization activity has also been important. Customers have been mainly institutional: Ministry for Transports (*Ministerio de Transportes, Movilidad y Agenda Urbana: Dirección General de Carreteras DGC, Puertos del Estado*), Ministry for Ecological Transition and Demographic Challenge (*Ministerio para la Transición Ecológica y el Reto Demográfico: DGA, Confederaciones Hidrográficas, DGCEA*); work has also been carried out

for autonomous communities, private companies and for the European Union (R&D projects; CEN). In terms of human resources, in 2019 the laboratory has had a staff of 44 people, of whom 24 were civil servants (16 of Group A1 with degrees in Geotechnics, 7 of whom with PhD's degree), 1 R&D contracted researcher, and 19 technicians, most of them of Group 3. In terms of its technological capacity, the laboratory has a complete set of geotechnical test equipment and a number of unique testing devices and installations, among which the following can be highlighted: the CEDEX Railway Track Box; the direct shear box of 1 cubic meter; the set of soil dynamics testing equipment, including new resonant column test and torsional shear test equipment; in terms of field equipment, the self-boring pressiometer, the seismic piezocone, and the set of seismic and electromagnetic geophysical equipment.

The main activities in 2019 are highlighted below, classified by theme:

Road Geotechnics: for the Directorate-General of Roads of the Ministry for Transports, the GL/LG has carried out technical assistance studies and instrumentation work to monitor pathologies in many points of the State road network (figure 1).



Figure 2.
Ground treatment by deep mixing at SE-30 ring motorway, Sevilla.

Slope cut on the A-7 motorway next to the town of Carchuna (Granada); pathologies on different roads in the province of Cantabria; report on the extension of emergency works on the A-48 motorway (Cádiz); pathologies at km 76+200 on the Jaca-Huesca road of the A-23 in Nueno (Huesca); stabilization of instable rock blocks on the N-630 road. Pola de Gordón (Lion); embankment pathologies of km 298,000 of the A-40 motorway (Cuenca); deformations on the A-4 motorway between km 333+000 and km 333+740 on both margins and 340+000 to 340+700 on the left margin (Jaén); pathologies at two points of the A-44 motorway in the surroundings of La Guardia (Jaén); pathology in the section between km 12+625 and 13+000 of the Burgos BU-30 ring road; pathologies observed in different km of N-432 road (Córdoba); tunnels of Ramoncillos on the Mediterranean highway, in the Polopos-Albuñol (Granada) section; analysis of the pathologies existing in the E2 structure of the section “Central Térmica-CN-340(A) of the MA-22 motorway, Access to the port of Málaga (2nd Phase)”; pathologies around the false tunnel of km 851 of the N-420 road (Coll de la Teixeta, Tarragona). It’s also worth noting the construction support provided during the soil treatment by Soil Mixing (figure 2) in the SE-30 ring road (Seville); and the technical assistance provided during a fracture grouting treatment (figure 3) in Virreinas highway link (Málaga).

Railway Geotechnics: the activity of the GL/LG covers four fields of action: 1:1 scale tests in the CEDEX

Railway Track Box, on-site instrumentation and testing in railway sections, modelling of railway sections, and laboratory tests on materials used on railways. In 2019, the work in the field of numerical modelling, mainly aimed at the analysis of the tests carried out in the Track Box, as well as at the study of problems related to critical speed, is to be highlighted. Inclined load tests have been carried out in the Track Box on a prototype of slab track, following the research line carried out for the Capacity4Rail project. As to a project on methods of determining the critical speed of railway sections, two approaches have been worked on: 1) the method based on the dispersion curves of the system consisting of railway layers, embankment and natural ground; and 2), the method based on the ground rigidity matrix (Moving Bell program – E. Kausel MIT 2018) for the determination of vertical movements of the track. Work has also been done on a CEDEX R&D project about the geotechnical characterization of the sleeper-ballast contact (figure 4). In the normative field, work has been done for the regulatory drafting committee of UIC (International Union of Railways).

Port Geotechnics: in 2019, various geotechnical consulting work has been carried out for the National Port Authority (*Puertos del Estado*). Several geotechnical projects have been analysed: extension of the new commercial pier of the port of Marín; adaptation of the Raíces pier, for new traffic, in the port of Avilés; advice in the construction phases of the northern expansion of the

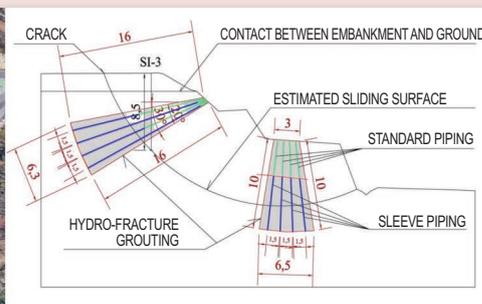


Figure 3.
Treatment by fracture grouting at Virreinas road link, km. 241+200 to 241+300 (Málaga).

Figure 4.
Geotechnical characterization of the sleeper-ballast contact.



Figure 5.
Access to the new terminal of the port of Cádiz.



South pier of the port of Huelva, involving 33 m long sheet piles, record in Spain; repair project for correction of water infiltration in the cut-and-cover access tunnel to the new terminal of the port of Cádiz (assessment on sealing alternatives, on-site testing, technical support during the implementation phases); dredging and expansion of the sea access to the port of Cádiz. With regard to the analysis of geotechnical pathologies, work has been carried out in the port of Huelva: auscultation by geophysics and penetration tests of the chimneys that have emerged and the defects detected at concrete walls; the T-element diaphragm wall of the South pier of this port have also been analysed; and secondary compression settlements at the port of Huelva esplanade have been monitored. Technical support has been provided to the Port Authorities in the resolution of different conflicts and disputes, in particular: to the port of Cádiz, on the concrete walls of the cut-and-cover tunnel of the access to the new terminal (figure 5); to the port of Huelva, on tests for the fill from which the sheet piles will be driven; and to the port of Cádiz, related to characterization tests for materials around sheet pile walls.

Environmental Geotechnics: a collaboration has been initiated with the Centre of Environmental Studies of CEDEX, CETA, for two studies concerning, the first one, the environmental remediation of the Vinalopó River Basin; and, the second, the prevention of contamination

by lindane leaching in Gállego River. In the field of the re-use of waste materials in geotechnical works, a communication has been presented in Portugal on the historical and present works of the Geotechnical Laboratory on this topic. Also, a possible collaboration for re-using demolition and construction waste materials in Madrid Nuevo Norte urban development project has been analysed.

Geotechnics of Hydraulic Works: technical assistance activity to the DGA has been reactivated, mainly in the field of dam geotechnical pathology analyses. The following dams and problems are being studied: degradation and instability of the upstream slope of Alcorlo embankment dam (Tagus); signals of karstification under the foundation of La Tajera arch dam (Tagus); downstream slope pathologies in Mairaga embankment dam (Ebro).

R&D&I: in the field of R&D&I, the development of the applications of geophysical techniques available in the laboratory is underway. Different lines of research have been prepared to contract 8 new researchers, who started working on 31 December 2019. These lines are as follows: advanced numerical modelling for the study of geotechnical pathologies of public works and historical monuments and interpretation of *in situ* tests and instrumentation (2 researchers); numerical modelling of the dynamic behaviour of railway infrastructures;

development of dynamic testing on soils and ballast; development of geotechnical auscultation, ground treatment and control techniques for coastal-port structures (2 researchers); development of geotechnical tests for rocks and coarse granular materials; and study of theoretical and experimental geotechnical aspects of unsaturated soil behaviour.

Standardization: work has been done on UNE's national standardisation committees, in particular UNE Committee CTN 103-Geotechnics and subcommittee EC-7 of Committee CTN 140-Eurocodes Structural, of which CEDEX holds the Presidency, as well as in the various subcommittees and working groups thereof. Work has continued on the drafting of the future Eurocode 7, Geotechnical Project, commissioned by CEN TC-250, through the Nederlands Normalisatie-Instituut (NEN). In the railway field, work has been carried out on the preparation of two documents for UIC (International Union of Railways) regulatory drafting committee: UIC-IRS 70719 (Earthworks and track construction bed for railway lines) has been completed; whereas work on the drafting of UIC-IRS 70722 (Maintenance and improvement of earthworks and bed track of existing lines railway lines) has begun.

Technology Transfer: in 2019, the 37th edition of the *Master's Degree in Soil Mechanics and Geotechnical Engineering CEDEX-UNED* was held. Also, a Technical Seminar on Presentation of the Spanish National Annex of Eurocode 7 and the Guides for the Design of Foundations according to Eurocode was organized on October 2-3. Efforts have been made to maintain CEDEX as the main meeting point of the geotechnical sector in Spain. The Geotechnical Laboratory hosts the headquarters of the two main geotechnical scientific societies of the country: the Spanish Society for Soil Mechanics and Geotechnical Engineering (SEMSIG) and the Spanish Society for Rock Mechanics (SEMR) and has supported the activities developed by these two societies. The laboratory is member of different national and European technical platforms (ELGIP, GEOPLAT). The service of the geotechnical library of the laboratory is, for its part, the most complete one on this subject in Spain.

Laboratory Studies: geotechnical tests have been carried out through the Permanent Technical Service for different domestic and foreign clients. Laboratory tests have also been done within the framework of different contracts and research projects. In 2019 more than 25 reports of completed works have been issued, highlighting: direct shear tests in 1 x 1 meter box; tests on expanded clay aggregate impregnated with molten salts, for the study of contamination of a special foundation of a tank, storing viscous salts at 500 °C; light aggregate characterization tests; collaborations with

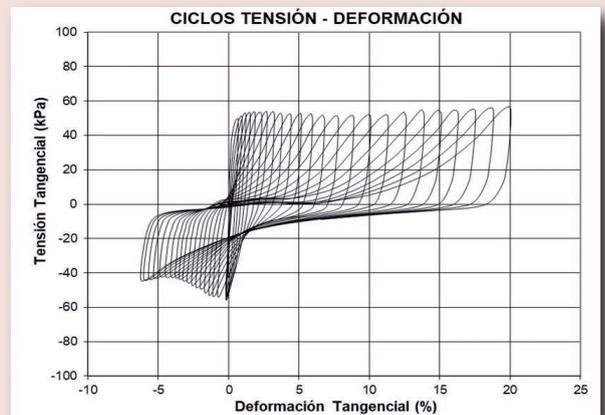
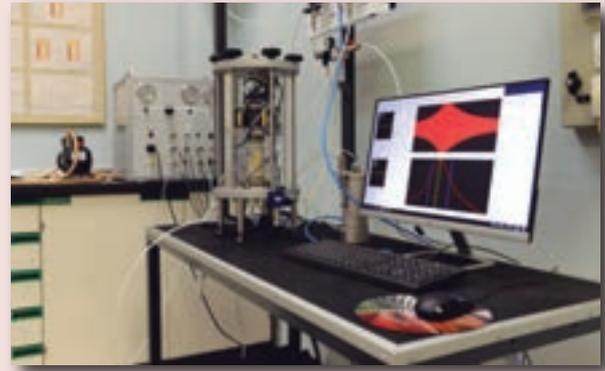


Figure 6. Studies in the dynamic testing section of the Geotechnical Laboratory.

different private companies and universities (UAC, UPM, UCM, USAL). In the chemistry section, more than 205 tests have been carried out for 8 different studies, highlighting the collaboration with LCEYM (testing on water and dam materials, zinc samples) and with CET (rubber powder leachate), a study on LOI determination procedure at 550 °C and estimation of organic matter content in soils. It should be noted the publication of CEDEX Monograph n° 141 "Chemical Analysis Tests in Geotechnics. Use of instrumental techniques", developed by a researcher of the laboratory based on his work of master's degree in the CEDEX-UNED Master's Course in Soil Mechanics and Geotechnical Engineering. With regard to the dynamic testing section (figure 6), cyclic tests for MAW Project of the University of Salamanca stand out; in relation to the new resonant column equipment, the establishment of test procedures, and tests on Ottawa's sand; and the development of bender elements applications in determining wave velocities in kaolinite samples and values of maximum shear module (G_{max}) in bentonite samples.



Certification of the ERTMS onboard equipment from Hitachi (Ansaldo).

During 2019, CEDEX Rail Interoperability Laboratory (RIL/LIF) has continued its main activities, i.e.: Lab test of ERTMS lines, ERTMS components certification tests and national and European R+D projects. The laboratory has also started an important activity, which is the creation of the "ERTMS National Laboratory". All these activities are explained below.

Related to the execution at lab of tests for new lines equipped with ERTMS, the most significant case has been the HSL Antequera-Granada tested at RIL during the first quarter of 2019. This line was open to commercial service on 26 June 2019. The line was tested at lab by integrating the two RBCs (Radio Block Center), equipping the 120 kms of the line. These RBCs are supplied by Siemens and they were tested by means of circulating a simulated train equipped with the On Board Unit (OBU), provided by Alstom. During the lab tests an error in the handover between the two RBCs of the line was detected. This early detection allowed, after the later reproduction of this problem in the test on track, a fast resolution of the problem as well as opening the line for commercial service at the date foreseen.

In the same line, in 2019 the RIL has executed the interoperability tests of an ERTMS line connecting Dakar with its airport. It's an ERTMS L2 line equipped with the Thales RBC (Baseline 2). On this line, a train equipped with the Alstom ERTMS On Board Unit baseline 3 (3.4.0) will

circulate. In this case, CEDEX RIL has performed the definition, execution and evaluation of the interoperability tests, demonstrating the correct circulation of a BL3 OnBoard Unit over a BL2 equipped trackside. This scenario is going to be reproduced in Spain in a short period of time when the new trains equipped with OBUs BL3 will run over the Spanish HSL, all of them equipped with ERTMS BL2.

In the last quarter of 2019, the RIL has integrated at lab the ERTMS equipment's of the Barcelona commuter line between Badalona and Mataró: the Bombardier interlocking, the Alstom RBC (Baseline 2), as well as the Alstom On Board Unit (Baseline 3). The integration of the Local Operation Post (PLO in Spanish acronym), as well as the ERTMS Control post (PCE in the Spanish acronym), together with the extended capacity of the RIL simulators, allows the execution of all kind of dynamic test scenarios as the following: routes setting, itineraries changes, unexpected red signals, temporary speed restrictions (TSR), simultaneous circulation of several trains, etc.

When it comes to the certification of ERTMS components, in December 2019 RIL has finished the tests of the Hitachi (formerly Ansaldo) On Board Unit (OBU) Baseline 3 (version 3.4.0). The final report has been issued in December, completing and finalizing a long period of tests to complete the official certification tests (Subset-076) for this ERTMS OBU BL3. This equipment is going to be installed by the

French TGV equipped
with the ERTMS equipment
certified at CEDEX RIL.



The Rail Interoperability Laboratory (RIL) Activities in 2019.

SNCF in the trains running within the French high-speed network. This is because it's part of the so-called "bi-standard OBU", together with the system TVM installed in the whole HS network of France. It's the first time that a baseline 3 equipment is tested in Spain by means of executing over 700 test sequences defined by the Subset-076 of the TS (Technical Specification of Interoperability).

As for R&D projects, CEDEX RIL has participated very actively during 2019 in two European projects both related to the use of Global Navigation Satellite Systems (GNSS), and more specifically Galileo, in the railways field: the first project is the ERSAT (ERTMS and SATellite) project that has finished in December 2019. This project has developed a methodology for the classification of any section of the rail track in order to check the viability to use satellite for a precise and reliable train location. A test campaign to characterize the line has been performed on a Spanish line between Almorchón and Mirabueno. The second R&D project, GATE4RAIL, is focused on developing a new platform to test at lab ERTMS lines using Galileo to localize the train. This project will be completed by the end of 2020.

Finally, another important aspect in the research and development activities of CEDEX RIL has been its involvement in several activities regarding Hyperloop, the very high-speed (1,000-1,200 km/h) transport system that is starting to be developed. The CEDEX RIL activities in this field are the following: 1) Delivery of the project "Acceleration and Levitation System FOR UltraRapid TRAIN-ALAS4TRAIN" to the RETOS call 2019, a research project

together with Ciemat and Zeleros company; 2) Possible development, starting in 2021, of a Hyperloop test track with the financial support of CDTI (Industrial and Technological Development Centre of the Spanish Ministry of Industry), by means of the new procedure "Innovation Public Tender"; and 3), CEDEX RIL has been nominated by the Spanish Ministry for Transports as the representative body in the meetings about Hyperloop organized by the European Commission (DG Move and DG Research), having attended two meetings in 2019.

Last but not least, during the second semester of 2019 CEDEX RIL has launched an initiative for the creation of the so-called "ERTMS National laboratory", by means of the signature of a Memorandum of Understanding (MoU) for this end. This MoU will be signed, on one side, by all public institutions involved in ERTMS, e.g. CEDEX, ADIF, AESF, RENFE and Ineco, and, on the other, by all ERTMS suppliers and users in Spain. The target of the creation of this facility at CEDEX RIL is to have a common place where testing all the lines equipped with ERTMS, by means of a cession of the RBCs by the suppliers and the maintenance of all the lines data updated by ADIF. In this way, the new trains entering the Spanish network will have a place for testing its interoperability, and for debugging the whole system before performing test on the real track. The real target is to minimize the tests on track to save time and money, and speed up the ERTMS deployment in Spain. This MoU was presented to the whole sector on a meeting held at CEDEX RIL on November 22, and is intended to be signed during the first semester of 2020.



CENTRAL LABORATORY FOR STRUCTURES AND MATERIALS

In 2019, the Central Laboratory for Structures and Materials (CLSM/LCEYM) has undertaken noticeable activity. As a result, 75 technical reports have been issued concerning high-level technical assistance, experimentation, and research and development in the field of civil engineering and building structures, and construction materials, for different public institutions and private companies.

Among the activities performed, those related to pathology and evaluation studies of all kind of structures (buildings, road and railway bridges, dams, breakwaters with important problems that may affect their functionality, structural capability and durability), have had special importance.

Besides, the Central Laboratory has continued its permanent activity in the drafting of technical codes, resulting in the elaboration in 2019 of the English version of the draft Spanish Structural Code.

The participation in different standardization and certification committees has carried on. This has resulted in issuing 60 rated reports for different clients. Likewise, the Secretariat of the International Association for Shell and Spatial Structures (IASS), has continued at the Central Laboratory, as is the case since the creation of the association.

In the **Area of Studies and Auscultation** of Structures, the study of the structural situation of the

Inspection of the cooling towers of the combined cycle power plant of Plana del Vent.





Dynamic tests have been carried out on an overpass structure.

warehouse halls in San Fernando de Henares (Madrid), former general warehouse of the company Galerías Preciados, has been concluded for the Infrastructure and Cultural Equipment Management, an autonomous institution of the Ministry of Culture and Sport. The study included the analysis of the importance of the processes affecting the durability of the structure, and the resistance of the reinforced concrete floors and columns within the building. Given the absence of technical documents describing the structure and its materials, the study was performed through holes performed in both floors and columns, and a study of the quality of the concrete based in multiple correlation of various types of tests.

Moreover, a new study on the structural importance of damages in a highway overpass has been executed for the Directorate-General of Roads. The post-stressed concrete deck of the bridge is affected by alkali-aggregate processes. Those processes were characterized, and both the drainage and the dynamic behaviour of the bridge were analyzed.

The Area has continued the coordination of the activity of CEDEX-Drone Operator, promoting the training of new pilots, the updating of the operative procedures, and the execution of actions and flights in the different centres and laboratories of CEDEX.

For the companies Naturgy and Alpiq, it has been conducted the inspection and structural evaluation of the cooling towers of the combined cycle power plant of Plana del Vent, in Vandellós (Tarragona). The structure is affected by chloride attack, in spite of the design criteria of the towers, and the repair and maintenance activities performed recently.

Also, this Area has provided specialized technical assistance in several problems of structural pathology and masonry affecting different buildings of CEDEX, such as those of the Centre for Studies on Ports and Coasts, and the Secretariat.

The Area of Structural Dynamics has carried out, for the Directorate-General of Roads, several dynamic tests with real traffic on a highway overpass, having four continuous spans of constant depth solid slab, supported on abutments and piers through neoprene bearings. The objective was to evaluate the structural condition of the bridge and its time evolution, from the point of view of the dynamic characteristics (own frequencies, modal forms, and damping), compared to previous dynamic tests, after having undertaken the actions of rehabilitation of the upper layer of the deck, waterproofing, and construction of a new asphalt layer.

A number of tests tests have been performed at the Seismic Simulator following the MIL-STD 167-1A standard "Mechanical vibrations of shipboard equipment", for a reformer-combustion chamber, and the IEC 61373:1999 standard "Railway applications - Rolling stock equipment - Shock and vibration tests", on a number of pieces of equipment to be embarked in railways, for the Abengoa and Albatros companies.

In the field of **Official Technical Regulations** related to structural safety, the work concerning the Management Commission of the Technical General Secretariat of the former Ministry of Public Works (Ministerio de Fomento) has been finished. The last report has been the English version of the Structural Code draft, which will replace the existing EHE-08 Structural Concrete Code and the EAE Structural Steel Code. The new code will for the first time establish requirements for the steel-concrete mixed structures, and will become a milestone in the Spanish structural regulations.

In the **Area of Materials Science**, intense activity has been accomplished in the field of concrete pathology, due to different chemical processes, as well as reinforcement corrosion processes.

A study has been finished for the Guadalquivir River Basin Authority, on the concrete of the Tranco dam (Jaén), affected by a process of leakage. The study has included the evaluation of the causes of the pathology, its likely future behavior and the effect on concrete properties

Additionally, a study of the concrete of the Navacerrada dam has been conducted for the company GEOSA, promoted by the Isabel II Canal. The aim was to detect possible chemical pathology owing to internal sulfate attack.

Core tests have taken place within the study of corrosion problems in the Levante breakwater at the port of Málaga, for Puertos del Estado (the Spanish Port Authority). Another study has been carried out on the severe corrosion problems in the shoulder of the Escombreras Southwest breakwater, at the port of Cartagena.

The research on the influence of curing concrete with sea water has been continued. This is a very important issue for the construction of floating caissons. Chloride diffusion tests and other durability tests have been performed on laboratory made samples and cores



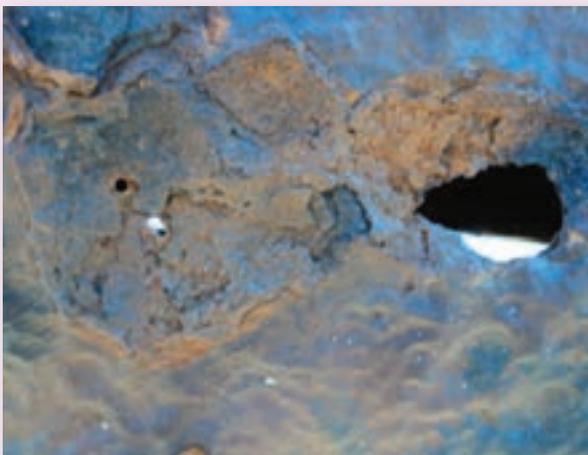
Corrosion problems at the outer wall of the shoulder of the Levante breakwater at the Málaga harbour.



Above. Fracture of a stainless steel bar.



Centre. Dynamic test on a balise profile.



Below. Corrosion in steel sheet of dam gates, San Juan dam.

obtained from submerged caissons at the port of Barcelona.

In the **Area of Construction Products**, the activity as external verification laboratory for the Ministry of Industry, Trade and Tourism, has continued. It consists of tests for the homologation of reinforcing and prestressing steel to be used in concrete, according to the official Code requirements.

Tests on drawn wires for electrowelded meshes have been done for foreign steel companies, which sell their products to the Spanish market.

The 2019 Permanent Technical Services for Steels for Concrete and Structural Steels have executed many rated tests, with public prices, for different clients.

Evaluation of prestressing steels, drawn wires, wire rods for meshes and prestressing steel, and electrowelded meshes have been made for the CTC-017 Certification Committee on Steel Products for Concrete and Concrete Reinforcing Steels.

It has continued the testing on different products for the CTC-036 Certification Committee on Steel Tubes and Hollow Profiles.

Equally, many rated reports have been delivered to the CTC-046 Certification Committee on Steel Profiles, Bars and Sheets.

For the AENOR Quality Mark, it has carried on the conduction of tests on cast iron elements for pipes. They have been done for both Spanish and foreign steel factories.

These activities require the ENAC accreditation of the Quality Management System, according to UNE-EN ISO/IEC 17025:2017 standard, and the performing of frequent inter-laboratory tests, mainly on all accredited tests.

For ADIF and other railway suppliers, a fatigue test has been carried out on the cantilever bearing profiles of balises, which are anchored to the rail lane.

The forensic engineering studies on steel pieces of existing structures have gone on. For the Directorate-General for Water, the pathology of the substituted gates of the San Juan dam, in Madrid, has been analysed.

In the **Area of Materials**, within the pool waterproofing field, a new Collaboration Agreement has been signed with Balsas de Tenerife and the Water Island Council of La Palma. Also, a new Agreement has been signed with the Taibilla Canals Commonwealth. Both relate to the study and monitoring of the behaviour of the waterproofing geomembranes installed in the pools managed by those institutions. In August 2019, a collaboration was initiated with the Directorate-General for Water for drafting of a *Practical Guide on Inspection and Monitoring of Geosynthetic Barriers used for Pool Waterproofing*.



Montaña del Arco pool.
Island of La Palma.

On the other hand, chemical tests accredited by the National Accreditation Entity (ENAC) have been carried out for the certification of structural steel products, through optical emission spectrophotometer with spark excitation, melting furnace with detection by measuring thermal conductivity and induction furnace with infra-red detectors.

Furthermore, tests have been performed for the analysis of several concrete pathologies, such as chloride and sulphate determination, and mineralogic analysis through X-ray diffraction.

This Area has taken part in interlaboratory test programs organized by the Secretary of the AE/CTC-015 Cement Certification Technical Committee.

In the field of road traffic signs, a large number of reports have been issued on the checking of the indicators regarding the retro-reflection of road markings and vertical signalling, all within the "Commission to an instrument personified by the

Directorate-General of Roads" for the technical assistance in the verification and checking of the indicators used in the current highway concession contracts (2018-2021).

The Area has continued work on the agreement with 3M España SL for the study of the behaviour of different retro-reflective microprismatic materials for signalling.

The LCEYM is accredited by ENAC in the **Quality Management System (QMS)**, under UNE-EN ISO/IEC 17025, as a testing laboratory in the area of Physical-Mechanical and Chemical Tests on Metallic Materials. In addition, it maintains the Internal Calibration Unit, with ENAC traceability, for calibrations and verifications of dimensions and mass.

In 2019, it's been updated the Quality Manual, as well as 4 Quality procedures, 4 guides, and 11 forms. The rest of the documentation will be revised and updated in accordance with the new versions of UNE-EN ISO/IEC



Equipment for chemical tests on steels.

17025:2017 and the ENAC documents. The activities of the QMS will be evaluated by ENAC in April 2020. It has begun the modernization of the design of the reports in the 6 databases that record the activities of the QMS.

The Network Q Unit, supporting the documentation archive of the QMS, has been maintained and updated. Access and writing allowances have been enlarged, in order to make easy the diffusion of the documentation.

The Central Laboratory internal auditors team has kept on making the internal audits, and coordinates the maintenance of the QMS of the three implied centres of CEDEX (the Centre for Studies on Applied Techniques, the Railway Interoperability Laboratory, and the Central Laboratory).

The CLSM/LCEYM is part of the CEDEX Multi-Site Certification of the UNE-EN ISO 14001 Environmental Management System, and is evaluated by the Certification Entity SGS. In this respect, it has met the targets set, and has continued raising the awareness of personnel regarding environmental matters, waste recycling, clean point maintenance, and energy saving.

Courses were held on Equipment calibration, Evaluation of the performance of the Intercomparison reports, and Tools for the Environmental Management System.

The Central Laboratory is committed, through its EMS, to achieving the Sustainable Development Goals (SDGs), of the 2030 Agenda, and the European Commission's Green Deal.



Volumetric equipment placed on a drying rack.

The Centre for Studies on Applied Techniques (CSAT/CETA) of CEDEX develops its activity around six areas of action:

- Climate Change and Air Pollution
- Environmental Noise
- Industrial Environment
- Environmental Engineering
- Environmental Restoration
- Water Radiological Quality and Applications of Environmental Tracers and Isotopes in Hydrology

In these matters, the CETA provides specialized technical assistance to the Administration and other public and private entities, promotes and participates in national and international research, development and innovation projects, engages in technological networks and national and international working groups, and transfers the knowledge through dissemination, training and cooperation activities.

The Area of Climate Change and Air Pollution works on the development of methodologies that allow progress towards the decarbonization of activities to the field of transport infrastructure, as well as initiatives that promote energy saving, which raise awareness in agents involved in practices that reduce their energy consumption and,

consequently, greenhouse gas (GHG) emissions and other polluting emissions into the atmosphere.

After the development of the **Methodological Guide for the Calculation of the Carbon Footprint in Ports**, proposed with the aim of serving as a support tool for Port Authorities, in 2019 CETA has continued the collaboration with Puertos del Estado (PE) and different Port Authorities for the application of the calculation of the carbon footprint at the port of Cartagena, and for the implementation of an operational modeling of dispersion of atmospheric pollutants within the SAMOA project (Meteorological and Oceanographic Support System of the Port Authority), being at each port managed by these authorities. This project seeks to obtain an operational modeling of dispersion of atmospheric pollutants in ports, evaluating the contribution to atmospheric pollution of port activities in cities near ports, which results in the improvement and management of port operations.

Internally, an assessment by CEDEX's **carbon footprint in 2019** has been carried out following the GHG protocol methodology, whereby the calculation of the carbon footprint of scope 1 + 2 is addressed. This tool allows to know the origin and magnitude of emissions at the organization level and thus reduce energy costs and GHG emissions, contributing to the fight against climate

Presentation at the UNE committee meeting (CTN 323 Circular Economy) held at CEDEX.

| Estado de acuerdos | | |
|---|--|--|
| Acuerdo | Acciones realizadas | Estado |
| 6. Alianza con MITECO para despliegue del Pacto por una ECircular | MITECO involucrado en: - CCEC - CTN 323 | Buena base para tratar temas de interés común en materia de EC |
| 7. Documento de sensibilización para CTNs | Punto específico del orden del día | |
| 8. Coordinación entre CC | 2019-07-05 Reunión de coordinación de Presidentes y Secretarios de las CC | Reuniones de coordinación |

change. It includes a section of the **Improvement Plan**, which outlines the measures to be implemented to reduce the carbon footprint in the next time horizon.

The Environmental Noise Area keeps the maintenance and updating of the **Basic Information System on Acoustic Pollution (SICA)**. This Area collaborates with the Directorate-General of Environmental Quality and Assessment (DGCEA) of the Ministry for Ecological Transition and Demographic Challenge (MITERD/MITECO), providing technical assistance to comply with the Directive 2002/49/EC, and the Noise Law and its regulations regarding reception, verification of formats and preparation of communications to the European Commission of **strategic noise maps and noise action plans** from the authorities responsible for their elaboration (other departments of the Central Administration, autonomous communities, local authorities, etc.).

The Area of Industrial Environment set out in 2019, focusing its activity on works related to the **circular economy** due to its weight in the policies of the European Union and its potential to solve, among others, environmental challenges. Within this field, the main activity has been aimed at establishing circularity measurement indicators.

CETA holds the presidency of the Technical Committee for Standardization of UNE (CTN 323 Circular Economy), made up of more than 75 entities and whose objective is the elaboration of norms of general application in circular economy.

The revegetation of the edges of linear infrastructures with native plants represents an opportunity for the conservation of pollinators in areas subject to intensive agricultural practices.

Since 2018, **the Environmental Engineering Area** has been developing the **Roads and Pollinators** project, which analyzes the impact of the fragmentation of pollinator habitats due to roads in both rural and suburban areas. It evaluates both the roadside effect and the direct running over of pollinators by vehicles, allowing a large-scale analysis of the pollinator community as a whole. The project is part of the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions on **the EU Pollinator Initiative** of June 2018, which states as Priority I: "Improving knowledge about pollinator decline, its causes and consequences".

The Environmental Restoration Department is focused on the design and monitoring of ecological restoration actions over degraded ecosystems, mainly in fluvial





Beginning of the works of study of the Royal Palace of Aranjuez's estuary (December 2019).

ecosystems. The department follows a methodology consisting of geomorphological, hydrological and ecological characterization of the area of study, the design of alternatives for restoration and the interpretation of results obtained in the hydraulic models, looking to select the restoration alternative that fits better the objectives of the project.

In 2019, **the environmental study of the Royal Palace of Aranjuez's estuary**, commissioned by Patrimonio Nacional, was completed. In addition, **the study of alternatives for the integral restoration of the Vinalopó River (Alicante)**, a cooperation agreement signed between Generalitat Valenciana and CEDEX, has started. This project has the backing of the Directorate-General for Water (DGA) of the Ministry for Ecological Transition and Demographic Challenge (MITERD/MITECO), and the Júcar River Basin Authority. Also, the Department has been providing technical assistance to MITERD in **the monitoring of the ecological flow regimes**, a line of work in collaboration with the Centre for Hydrographic Studies (CEH) that is expected to continue during next years. The purpose of this technical assistance is to establish the relationship between the ecological flow regime and the ecological state of water bodies where they're defined. Finally, remarkable progress has been made in the **DRAINAGE project for flood risk management**, launching the project website (<http://drainage.cedex.es/>), and giving the first steps in the use of drones to carry out topographic surveys and vegetation characterization. A promotional video of the actions carried out in June 2019 has been edited.

From an educational point of view, the department has tutored a student in her External Academic Practices Program, included in the Degree of Environmental Engineering of the E.T.S. Ingeniería de Montes, Forestal y del Medio Natural (total practice hours: 624 h, 24 credits). Moreover, Promoter-Observer Entities (EPOs) were informed of the advances in the development of the DRAINAGE project, with presentations held in Madrid and Valladolid.

In the field of **Radiological Quality of Water**, CEDEX has been assigned by the Nuclear Safety Council (CSN) the development of two **Programmes of radiological surveillance of the aquatic environment. Dense and High-Sensitivity monitoring networks**, for Spanish surface inland and coastal waters. Gross alpha, gross beta, residual beta, tritium activity and gamma spectrometry are determined in the Dense Network, in water samples of some 90 monitoring stations distributed throughout the national hydrographic network and 15 stations in the coastal environment for marine waters. Cesium-137 and cesium-134 activities are measured in the High-Sensitivity Network in four monitoring stations, two of surficial inland waters and two of marine waters. This work is performed within the framework of the Spanish Environmental Radiological Surveillance Network (REVIRA), managed by the CSN, in compliance of Articles 35 and 36 of the Euratom Treaty. The results of REVIRA are made publicly available on the CSN website <https://www.csn.es/kprgisweb2/index.html?lang=es>.

In the field of **Tracers and Environmental Isotopes in Hydrology**, CEDEX is mainly involved in the application

of these techniques to water and hydraulic infrastructures management. The **Spanish Network for isotopes in Precipitation (REVIP)** is a project managed by CEDEX in collaboration with AEMET, which has a national and international projection in support of UN R&D projects with a wide range of environmental applications, including climate change. REVIP data are integrated with all sets of information gathered from other *ad hoc* studies conducted by CEDEX to provide reference isotope values for precipitation, surficial and ground waters. These reference values are useful to trace and date studies in water bodies to assess water provenance, residence time and the contaminant fate. It's noteworthy the application, in 2019, of these techniques to **studies of watertightness in dams (Tous, Bellús)** for the Júcar River Basin Authority.

Within the framework of the projects and studies detailed above, numerous training and dissemination activities have been carried out, in accordance with the purpose of CEDEX. Among others, it's possible to highlight the professional tutorials that have been directed in **the Area of Environmental Engineering** for the completion of master's final projects (in the University Master's Degree in Ecosystem Restoration at the University of Alcalá, and in the Master's Degree in Biodiversity at the Autonomous University of Madrid), as well as the completion of Curricular External Academic Practices included in the Degree in Environmental Engineering of the E.T.S. in Forestry and Environmental Engineering, from 25/11/2019 to 31/01/2020 (total hours of practice: 312 h, 12 credits).

Through the framework of the application of **Tracers and Environmental Isotopes in Hydrology**, CEDEX



Vinalopó River. Upstream from the confluence with the Salinetes stream, in the municipality of Novelda (October 2019).

has collaborated in the organization of several events and outreach activities, such as “Hidrogeodía 2019-Lagunas de Ruidera: water made stone”(organized by the Spanish Group of the International Association of Hydrogeologists, which took place at the Lagunas de Ruidera Natural Park, Ciudad Real, 23 March 2019), and the conference “¿How old is groundwater?”, held during the “Science Week” at the Illustrious Official College of Geologists, Madrid, 7 November 2019. It has also participated in the “Training Course on Water Isotope Analysis by Laser Spectroscopy”, organized by the International Atomic Energy Agency (Vienna, Austria, 4-8 November 2019).



Howell discharge valve in Bellús reservoir.



Figure 1. Ship maneuvering study for the external extension of the port of Melilla.

In 2019, the Centre for Studies on Ports and Coasts (CSPC/CEPYC) has continued an important activity in all areas of its concern, mainly providing service to the public sector in the Port, Coastal, Maritime Transport, and Marine Environment areas. Plus, an action for the private sector has been carried out.

The activity has been reflected in 57 reports on high-level technical assistance and R&D works in the different fields of activity of the centre. Of these, 56 have been executed for the public sector, with 21 within the scope of the Ministry of Fomento: 4 for the National Port Authority, 15 for various Port Authorities, and 2 for the Permanent Commission for the Investigation of Maritime Accidents and Incidents (CIAIM). In the case of the Ministry for Ecological Transition, 36 reports have been prepared: 33 for the Directorate-General for the Sustainability of the Coast and Sea (DGSCM), 2 for Waters of the Mediterranean Basins S.M.E., S.A. (Acuamed), and 1 for the Spanish Office for Climate Change. Moreover, for the private sector, 1 report has been issued for Dragados UK company.

Actions in the port area have included both technical assistance, and R&D&I activities. The first has been mainly based on experimentation with physical and numerical models, highlighting the work to modify the configuration of the North Basin of the port of Valencia, which has included studies on a numerical model of maritime climate and water basin disturbance, tests on a physical model –water basin

disturbance and behavior of moored ships (figure 1)–, and simulation of ship maneuvering in real time, which will end in 2020. All these works have determined that the extension of the current basin is not necessary, estimated at 515 m in the preliminary studies of the Port Authority, with the consequent economic savings, and the suppression of potential environmental effects.

Other technical assistance works have included updating the dredging inventory of state-owned ports, and actions of various kinds in the ports of Pasajes, Bilbao, Melilla, Cartagena and Palma de Mallorca. Of these, the last three stand out. In Melilla, as a continuation of the work undertaken in 2018 for the expansion of the port, a study has been carried out on a numerical model of agitation and currents. In Cartagena, the actions for the expansion of the Escombreras Basin will go on in 2020 with studies in physical and numerical models, and with simulation of ship maneuvering in real time. In Palma de Mallorca, the works for the design of the new configuration of its SW Basin have included ship maneuvering simulation in real time, and an operability study, which stands out for its innovative nature, using results of the simulation study, and data from the Automatic Ship Information System (AIS) relative to the ships that currently operate in said basin (figure 2).

As with previous years, R&D activities in port matters have covered various fields: physical environment, infrastructures, environment, and risk analysis. Concerning physical



Figure 2.
Three-dimensional physical model of agitation and moored ships for the study of the extension of the Escombreras dock (Cartagena).

environment, the study for the **climatic characterization of the design waves in port environments has been completed to support the Maritime Works Recommendations (ROM) Program**, with the inclusion of the Mediterranean façade. In the infrastructure context, the study of the evolution of breakdowns in rubble mound breakwaters has begun, through tests on a physical model, proposed by the National Port Authority regarding the new design methodologies proposed for this type of structures in the ROM 1.1. Breakwaters.

In the environmental field, a pilot study has been prepared for the **pre-selection of areas for dumping dredged material** in accordance with the Guidelines for the Characterization of Dredged Material and its Relocation in Waters of the Maritime-Terrestrial Public Domain, with application to the port of Huelva, and the study on risk associated with maritime traffic and ship maneuvers in ports based on AIS data has continued.

In the specific case of **navigation**, two studies have been undertaken to determine the maritime climate conditions in the course of two wrecks of fishing vessels: the Dorneda, which sank about 300 miles off Puerto Madryn (Argentina), and the Without Wanting Two in front of Cape Finisterre.

As for **coasts**, another of the sectors in which the CEPYC is an institution of national reference, numerous works have been performed to design actions for the defense of the coastline, and for the environmental protection of the coast and sea. Coastal engineering works applied to the protection of the coast against the risks of erosion and climate change have included experimentation with physical and numerical models, measurements in nature, and studies of coastal dynamics. Within the first group -physical and numerical modeling-, and as an extension of the test for **erosion control at Sardinero beach (Santander)** carried out in 2018, a detailed study has started to mitigate the overtopping caused by the solution adopted. It was produced on the promenade (avda. M. G^a Lago), by using a numerical model SPH and another physical one on a large scale -1: 10- (figure 3).

With respect to the **measures in nature**, an important effort has been made, in support of the DGSCM (now the Directorate-General for the Coast and Sea), in monitoring the **emergency actions of 2018 in the Gulf of Cádiz**, to which bathymetries have been carried out on various beaches in the provinces of Huelva and Cádiz. Also, the morphodynamic monitoring of the Zurriola (San Sebastián), Laredo (Cantabria), Salinas (Asturias), and Ensenada de Orzán (A Coruña) beaches has continued. In the matter of **coastal dynamics studies**, various works have been undertaken to improve the beaches of Flamingo (Lanzarote), Virgen de las Mareas (Pontevedra), and Barranquillo (Las Palmas), as well as the western coast section of Campo de Dalías (Almería) between beaches of Balanegra and Punta del Moro. Furthermore, it's been performed the storm characterization that hit the north coast of Tenerife in November 2018, particularly in the Garachico and Tacoronte areas, and the analysis of the compatibility of the submarine sands deposits of Gijón and Villaviciosa for the regeneration of the Salinas beach (Asturias). On the other hand, as a singular work, the plan for the **protection of the coastline of the Mar Menor** (Murcia) stands out, which includes a detailed analysis of the potential effects of Climate Change and a wide set of actions for the defense of its coastline (figure 4).

In the field of the **marine environment and protection of the sea**, it has actively participated in various committees and working groups of international conventions (OSPAR, LONDON and BARCELONA) for the protection of the marine environment, especially on issues related to impacts on the sea of human activities; while participation in the European directive implementation groups has been about the exchange of data and knowledge associated with the notification processes of the Marine Strategy Framework Directive.

The work related to Marine Strategies has kept on with the evaluation, within the second planning cycle, of the activities and pressures for the five marine demarcations –North Atlantic, South Atlantic, Estrecho/Alborán, Levantino-Balearic, and Canaries–, and the execution of the program of routine monitoring of microplastics on beaches. On the other hand, a

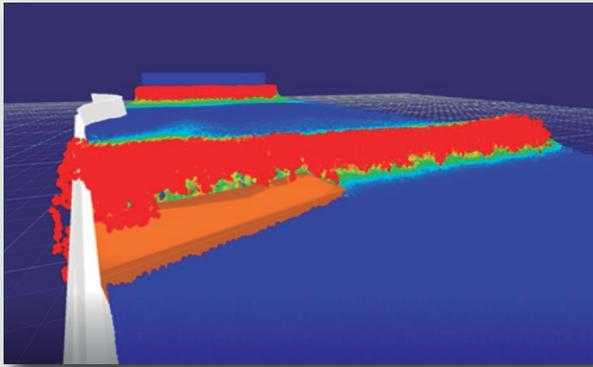


Figure 3. The Sardinero beach (Santander). Study in numerical (SPH) and physical models (E: 1/10), for the overtopping reduction on the seafront (avda. M. G^a Lago).

study has been started on the **contributions from rivers to the marine environment of microplastics**, and the design of a Marine Information System (INFOMAR) has continued. In addition, the exploitation of the AIS database prepared by CEDEX has allowed the characterization of maritime traffic in Spanish jurisdictional waters, the **study of inter-island maritime traffic in the Canary Islands in relation to the risk of collision with cetaceans**, and a first approach to the estimation of underwater noise associated with navigation.

Among the activities related to the impact of discharges to the sea, the environmental **modeling of the discharge system of the Valdeleñisco desalination plant**, and the review of the environmental monitoring plans for the discharge of the Torre Vieja desalination plant, have been addressed, the

latter as a continuation and in situ verification of the work developed years ago at CEPYC for the design of the sea discharge systems of desalination plants.

In relation to **Climate Change (CC)**, support has been provided to the Spanish Office of Climate Change for the implementation of the Plan to Promote the Environment for Adaptation to CC **Pima Adapta Costas**, so as to harmonize and integrate the work of the autonomous communities for the analysis of the risks associated with CC. Equally, the effects of CC on La Manga del Mar Menor have been evaluated within the aforementioned Plan for the Protection of the Coastline of the Mar Menor.

For the **private sector**, the centre has worked for Dragados UK company in the **expansion of the port of Aberdeen (UK)**, through the execution of various tests in a two and three-dimensional physical model, of the final phase of the port and of construction stages. Such tests were carried out in the Multidirectional Wave Tank in order to study the stability of the breakwaters, and the basin water disturbance provoked by the waves (figure 6).

One of the features of CEDEX, and CEPYC in particular, is its technological facilities - channels and tanks for physical experimentation, Ship Maneuver Simulator, and Marine Environment Quality Laboratory-, which in 2019 have begun their renovation and improvement, being underway those of the **Multidirectional Wave Tank and the Ship Maneuver Simulator**. Likewise, a new computer application has been put into service

Figure 4. Study for the protection of the coastline of the Mar Menor (Murcia). Proposal for actions and setback of the coastline due to the Climate Change.

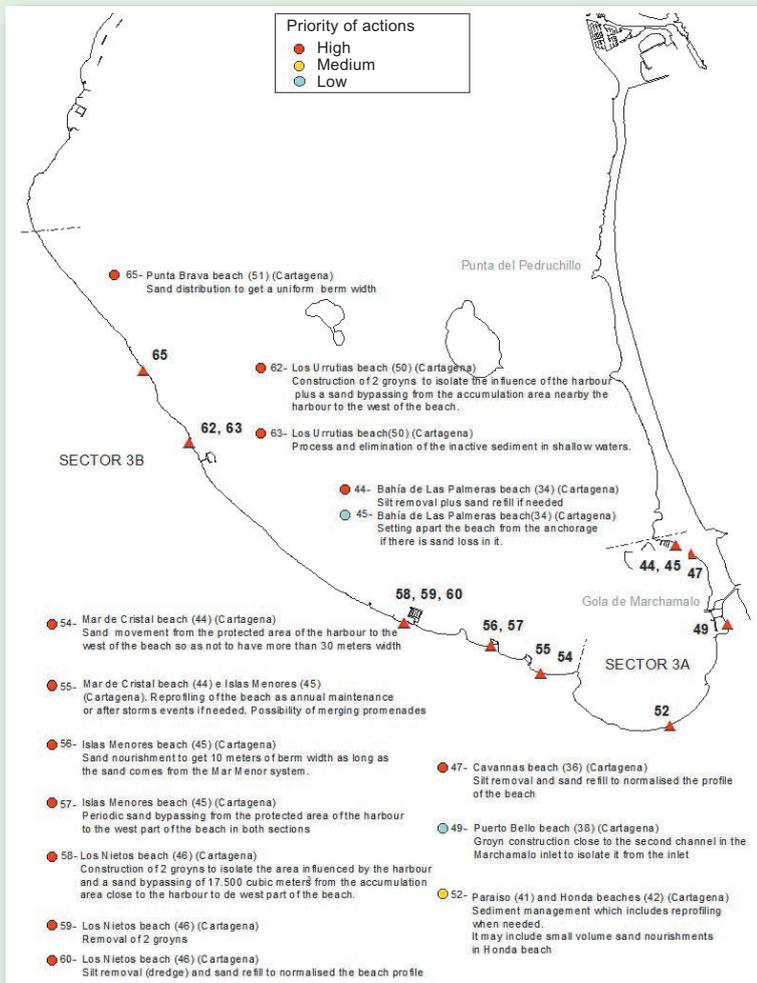




Figure 5. Microplastic sampling system in rivers.

for the generation of waves, wind, currents and tides, as well as for the acquisition and processing of data in physical model tests, and a new high-performance computer calculation equipment.

When it comes to **training tasks, dissemination of activities and participation in congresses or belonging to technical-scientific associations**, in the educational field, the *Coastal Engineering and Marine and Coastal Environment Course* stands out, of which three editions have been given for the staff of the Directorate-General for the Coast and Sea at CEPYC, and another at the Chamber of Commerce of Cuba in Havana. In terms of the dissemination of activities and participation in congresses, it's worth noting the intervention at the *Spanish Days of Coasts and Ports in Málaga*, the *XXXVIII IAHR Congress in Panama*, the *Forum on Ecological Flow and Ecological Hydraulic Engineering in Beijing*, the *International Forum on Higher Education of Hydro-Environment in Nanjing*, the *Seminar on Climate and Coastal Change in Paris*, and the *Conference on Digital Transformation at COP25 in Madrid*.

With reference to activities related to national and international associations, it has continued to participate actively in the

activities of the **International Association of Hydro-Environmental Engineering and Research (IAHR)**, through conferences organized jointly with the SpainWater group (CEDEX, the Directorate-General for the Coast and Sea, and the Directorate-General for Water), and in those of the World Association for the Infrastructure of Aquatic Transport (PIANC), directly and through its Spanish delegation: the Technical Association of Coasts and Ports (ATCYP).

All this range of activities has been possible thanks to a **team of 64 people, between officials and labor staff, highly specialized and of remarkable multidisciplinary nature**, which brings together different branches of engineering (civil and naval), as well as basic (physics, chemistry and mathematics) and applied (environmental, marine and biological) sciences. This has improved the transversal way of working, not only among the various areas of CEPYC, but also in regard to other CEDEX centres, an aspect that gives these teams strength, synergy, and ability to generate innovative lines of work. Finally, it should be highlighted that the potential of this team has been strengthened at the end of 2019 with the incorporation of eight higher graduates for R&D tasks, as it has happened in other CEDEX centres.



Figure 6. Expansion of the port of Aberdeen (UK). Physical model test. Final and construction stages.



CENTRE FOR HYDROGRAPHIC STUDIES



Cover images from the 2015-2016 and 2016-2017 Gauging Yearbooks.

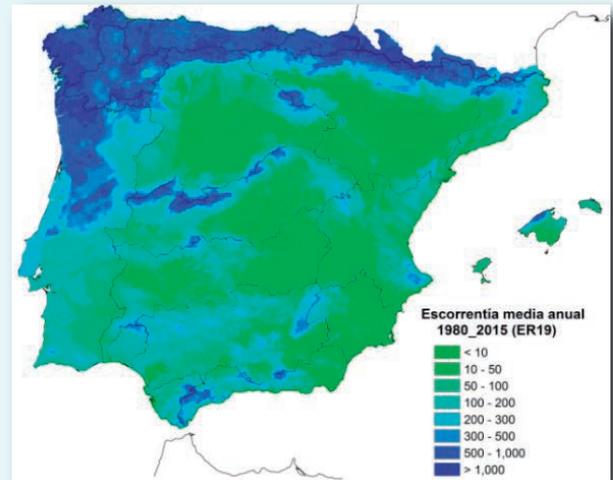
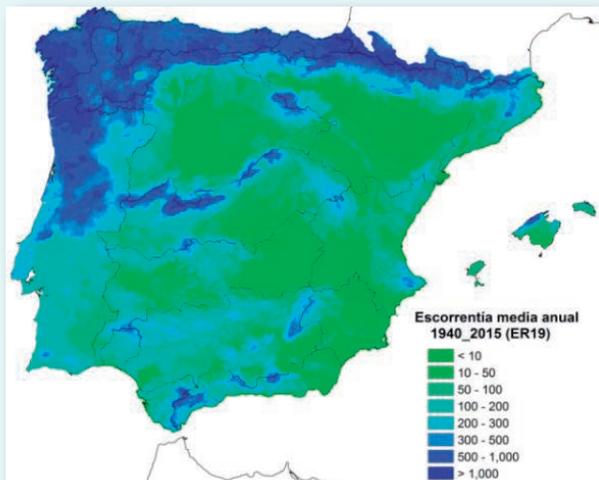
The main activities accomplished by the Centre for Hydrographic Studies during 2019 have been structured according to the purposes established by CEDEX Statutes in the field of inland waters and their natural or artificial infrastructures: activities related to the basic nature data, the knowledge of the resources and the water environment; standardization and regulations, as well as technical standards and specifications, and, lastly, advances in research, technological development and innovation.

The centre has provided specialized technical assistance to the Ministry for Ecological Transition and Demographic Challenge (MITERD/MITECO), and the Ministry of Foreign Affairs, European Union and Cooperation, as well as to the Development Bank of Latin America (CAF) and the private sector. Assistance to MITECO has been provided through the Directorate-General for Water (DGA) and the River Basin Authorities, the Directorate-General for the Coast and Sea and the ACUAES State

Society. In the case of Foreign Affairs, assistance has been provided to the programs of the Water and Sanitation Cooperation Fund at the request of the Secretariat of State for Foreign Affairs and for Ibero-America and the Caribbean.

In terms of education, the centre has organized several courses, attended courses organized by other institutions, and provided various educational stays. The diffusion and transfer of technology has been developed through publications, organization or participation in workshops, conferences and congresses, articles in journals and through the reception of various international delegations and national visits of institutional, academic and educational nature. Likewise, the centre has collaborated with different institutions, both nationally and internationally.

Except for specialized technical assistance, which is carried out at the request from the interested public



Annual run-off maps, period 1940-2015 and period 1980-2015.

organisms or through contracts with the private sector, the other activities have looked to meet the needs of the public water administration, working in close collaboration with the Directorate-General for Water.

Basic nature data

Updating the HIDRO hydrological database

The new data for the gauging stations, channels, reservoirs and evaporimetric stations corresponding to the hydrological years 2015/16 and 2016/17 have been fully loaded.

The monthly data of total precipitation, daily maximum precipitation, rainy days, maximum temperature, minimum temperature, monthly average temperature and monthly average temperatures of daily maximum, and minimum temperatures up to October 2018 have been uploaded. Data have been provided by the State Meteorological Agency (AEMET) for all its stations. Updating the geographic information corresponding to the location and placement of AEMET meteorological stations. Analysis of the change in the stations placement has been undertaken from the time of their registering with HIDRO to the present.

Preparation and publication of the Gauging Yearbooks corresponding to the hydrological years 2015-16 and 2016-17

Since its creation, the centre collects, analyses and publishes hydrometric data from the Official Network of Gauging Stations, provided by the River Basin Authorities, through the Directorate-General for Water, giving support to this Directorate in its work of dissemination and publication. The activities during the year 2019 of compilation, unification and validation of the information have allowed to conclude the work of elaboration of the gauging yearbooks of the hydrological years 2015/16 and 2016/17, which have already been published.

Knowledge of the resources and the water environment

Updating the inventory of water resources in natural regime

The results will serve as the basis for preparing the River Basin Management Plans for the third planning cycle (2021-2027). Calibration of the SIMPA simulation model by adjusting the four basic parameters of the model: maximum storage capacity in the soil, surplus coefficient, maximum infiltration capacity and discharge coefficient of the aquifer. The hydrological simulation of the period 1940/41-2015/16 has been carried out and the simulation period has been extended with two additional hydrological years, 2016/17 and 2017/18.

In 2019 the maps of potential evapotranspiration of the Canary Islands, the collection of maps of the atmospheric variables of the years 2016/17 and 2017/18 and the collection of maps of the different simulated variables of the period 1940/41 to 2017/18 (real evapotranspiration, soil moisture, infiltration, surface run-off, underground run-off, total run-off and accumulated contribution to the drainage network) have been provided to the Directorate-General for Water. The methodology and results of the new inventory of water resources were presented at a meeting of the Hydrological Planning Offices of the River Basin Authorities. Additionally, different request of information submitted by the River Basin Authorities have been answered.

At meetings with the Geological and Mining Institute of Spain (IGME), the groundwater simulation module has been finalized and refined. The programming of the new module has finished by adapting the interfaces of the SIMPA hydrological model and it has been tested with a hypothetical case in the Segura River Basin. The new module represents an improvement in comparison to a previous version, for it involves an extension and a greater definition of groundwater bodies (differentiating up to three vertical horizons); the recharge that the

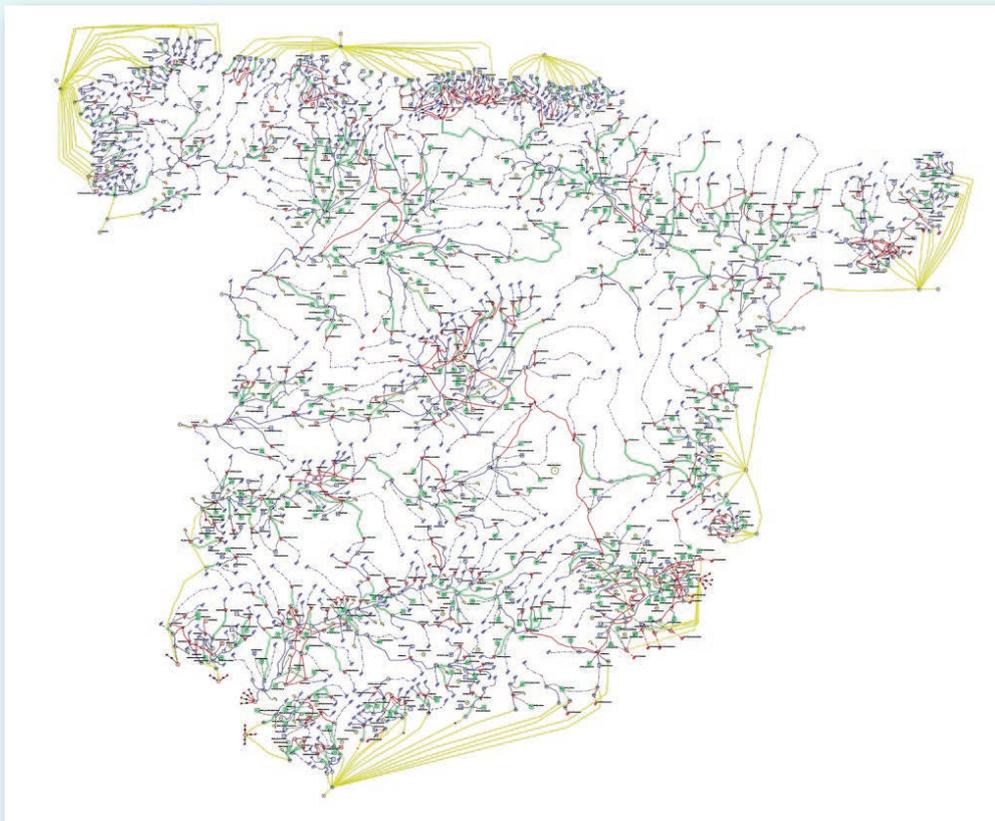


Diagram of the integrated model of the water resources system in peninsular Spain.

aquifer can accept is limited; lateral and vertical transfers are simulated between groundwater bodies; direct discharges to the sea, rivers and springs are simulated and the possible recharge of groundwater bodies from the river is also simulated.

Updating the integrated model for the national level analysis of the water resources systems of the River Basin Authorities, based on the information from the river basin management plans

Preparation, calibration and simulation of the national level unified models have been executed in each scenario of the river basin management plans, including the effect of climate change on the available water resources according to the terms established in the Hydrological Planning Instruction.

Updating the Spanish maximum daily rainfall map and the Intensity-Duration-Frequency (IDF) curves

The available information on rainfall and maximum intensities, from the AEMET measurement network mainly, has been reviewed and analysed. These studies have consisted of completing the initial series and preparing the annual maximums series, detecting abnormally high values, analysing trends to detect the possible existence of systematic errors in the data and eliminating very close stations with redundant information. Gathering information from other sources, such as Autonomous Communities networks and the Agroclimatic Information System for Irrigation (SIAR), has also been completed.

Determination of pollutants and substances included in the research control program, defined in the Royal Decree on monitoring and evaluation of the surface waters state and in the Water Framework Directive

The centre continues with the analysis of the general parameters (COD, suspended solids and TOC), including the determination of COD for the data provision to the European Commission, and the study of the substances included in the Watch List with the determinations of the compounds included in List I and the three compounds that have been added to List II (amoxicillin, ciprofloxacin and metaflumizone), at 36 control points selected by the River Basin Authorities (16 points at the outlet of treatment plants, and other 20 in the receiving environment).

Establishment of the rivers mouths and closing of the low-water lines along the coast

In 2019 the centre began to define the end point of the rivers mouths (outlet) and the closing of the coast line in these areas. The geographic information layer of the rivers that flow into the sea (and are or form part of water bodies) and of the basins that flow into them, has been prepared from the geographic information layers of the rivers and classified basins according to the modified Pfafstetter method (carried out at the Centre for Hydrographic Studies).

Standardization

The centre participates in the Spanish Association for Standardization and Certification (UNE), in the Technical

Committee CTN 149 Water Engineering, in the Technical Committee CTN 77 Environment and is member of the subcommittee SC1 Waters.

Regulations, technical standards and specifications

Pilot project for the elaboration of the “Risk of Reused Water Management Plan of the Pinedo-Acequia del Oro system”

The new European regulation on minimum requirements for reused water (in approval process) proposes a new procedure for reuse systems management based on the risk management. This methodology is novel and there is no experience in the EU in this regard. Therefore, since 2018 a demonstrative project is being developed to assess the implications of the new European regulation, to establish methodologies for its implementation, and to identify the changes to be made in our legislation.

Guide for the cost-benefit analysis of the structural measures of the flood risk management plans

The guide includes recommendations on different aspects of the cost-benefit analysis (selection of the analysis period, discount rate, profitability criteria, investment prioritization, etc.). However, most of the guide is about providing criteria for estimating the damage avoided by flood defence measures on different land uses. The methodologies have been applied to the case of the floods that happened in Jávea in October 2007.

Assessment of the climate change effects on the flood risks management

The centre has continued collaborating with the DGA and work has been done on processing rainfall information from the available climate simulations from the EURO-

CORDEX project. This information will be used as basis for estimating the possible climate change impact on maximum rainfall and, therefore, the impact on maximum flows.

Basic studies related to the hydrologic safety of dams and, in particular, for the hydrologic study of the Project and Extreme Avenues

Development of studies and methodologies that serve as basis for the elaboration of a methodological Guide for the calculation of the Project and Extreme Avenues.

Quantify the uncertainty associated with the estimation of very high return period quantiles, such as those required in the field of hydrologic safety of dams, under different adjustment hypotheses: making a local adjustment, using regional information and using paleo-floods or historical information. The analysis were conducted in three geographical areas of the Ebro, Tajo and Duero in order to take into account the statistical variability of flows in peninsular Spain.

Review of the proposal for technical standards for the design of works and facilities for run-off water management

The DGA asked CEDEX to review the proposal for technical standards on stormwater (prepared by a consultant with the participation of a large group of experts) because the document was highly complex and very ambitious in its scope and content, which generated doubts on its legal status and practical application. CEDEX's work has been oriented in two directions: first, analysis of the regulatory framework for stormwater management, necessary to detect deficiencies and determine the scope and necessary content of the standards; and second, technical study of the proposal.



Facility of the EMULSIONA project at the Hydraulics Laboratory.

Research, technological development and innovation

Collaboration with AEMET has continued in the European seasonal forecasting research project (MEDSCOPE). The first phase consisted of two simulations, for all the months of the period 1997-2017, with the SIMPA hydrological model, based on the temperature and precipitation data provided by AEMET (on the one hand, from the observational grid, and, on the other, through regionalization by analogues of the ECMWF ERA5-European Centre for Medium-Range Weather Forecasts).

The centre has participated as an associated entity at the meeting celebrated in Zaragoza of the research project CO-MICC (Co-development of methods to use uncertain multi-model based information on freshwater-related hazards of climate change; <http://www.co-micc.eu/>), which aims to jointly use global water models to support adaptation to climate change at various scales.

The activities of the project “Albufeira. Joint evaluation program of the water bodies of the Hispano-Portuguese hydrographic basins”, within the Spain-Portugal Transboundary Cooperation Program (Interreg-POCTEP), began in March 2019. The project objectives are to investigate and to establish common criteria in monitoring transboundary water bodies, to improve the integration of the environmental objectives of the Water Framework Directive and the Habitats Directive, and to raise awareness of cooperation in shared river basins. The project is promoted by the Directorate-General for Water of the Ministry for Ecological Transition and Demographic Challenge of Spain and by the Portuguese Environment Agency.

The Directorate-General for Water is undertaking new developments of the two-dimensional numerical model Iber for calculating flood zones in rivers. In this context, the centre is also optimizing the FORTRAN code of the model to improve its calculation performance and to reduce its computing times.

Juan José Rebollo Cillán defended his doctoral thesis “Influence of flow aeration in supercritical channel flows

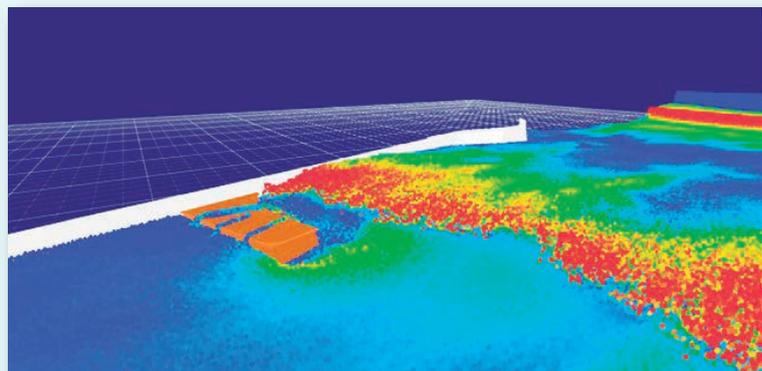
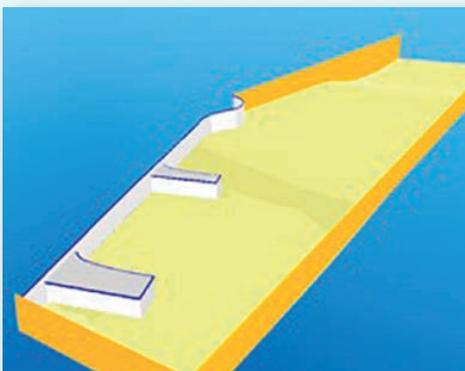
and in the energy dissipation efficiency in stilling basins”, at the Higher Technical School of Civil Engineering of Roads, Channels and Ports of the Polytechnic University of Madrid. The thesis has been developed in the facilities of the Hydraulics Laboratory within the framework of the coordinated project “EMULSIONA. Use of natural and forced flow aeration in dam spillways and extension of the field of use of the energy dissipation works by hydraulic jump”.

Specialized technical assistance

The centre has provided specialized technical assistance to the Directorate-General for Water to solve specific problems or supervising the work assigned to third parties, mainly through commissions from the River Basin Authorities or through participation in working groups.

- Limnological control of Lake Sanabria and monitoring of blooms in reservoirs (Duero RBA).
- Assessment of the impact of climate change on the water resources of the Spanish and Portuguese territories of the Miño and Limia River Basins (Miño-Sil RBA).
- Hydraulic study of the water discharge to the main river channel of the Zufre Dam discharge facilities by physical models with erodible bed (Guadalquivir RBA).
- Review of the European proposal for a Regulation on minimum requirements for reused water.
- Support in the supervision of the Study of solutions and preliminary projects of the actions in sanitation and wastewater treatments of the agglomerations of China, Butarque and South of Madrid.
- Supervision of the migration of the CAUMAX application from gvSIG to QGIS.
- Supervision of the update of the run-off threshold map.
- Study on the determination of the ecological flow regime established in the river basin management plans of the second planning cycle 2015-2021.
- Technical Assistance to the Conference of Ibero-American Water Directors (CODIA).

Collaboration with CEPYC in the study commissioned by the Directorate-General of the Coast and Sea for the



Numerical modelling with SPHERIMENTAL of El Sardinero Beach defence piers.

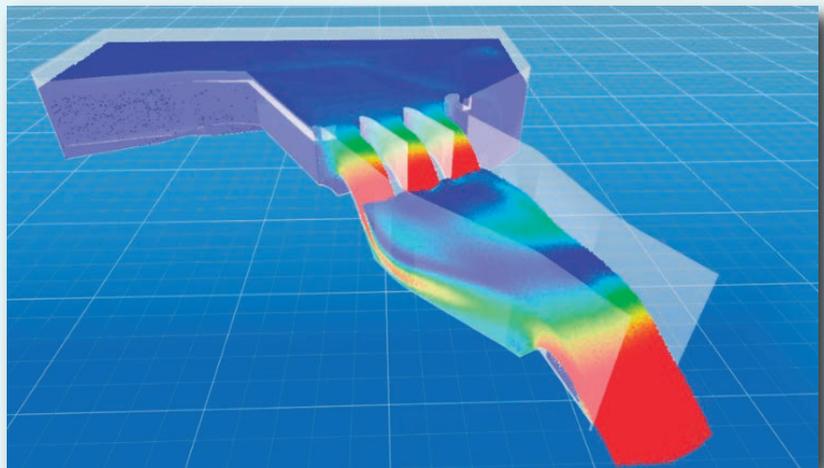
“Correction of the effect of the local erosion at the western end of the second beach of El Sardinero in Santander (Cantabria)”. Three-dimensional numerical simulations with the SPHERIMENTAL model have been performed in order to study the overruns that the incident waves produce on the promenade, and to analyse the influence of transverse structures arranged to control beach erosion.

In 2019, the study of odour generation problems in the new general sanitation system in Ribeira (A Coruña) was completed for Aguas de las Cuencas de España (ACUAES).

In the case of the Ministry of Foreign Affairs, European Union and Cooperation, specialized technical assistance has been provided regarding the programs of the Water and Sanitation Cooperation Fund (FCAS), at the request of the Secretariat of State for Foreign Affairs and for Ibero-America and the Caribbean. The work has mainly consisted of the orientation, supervision and review of the projects developed by the Fund in Bolivia, Panama, Cuba, Honduras and Haiti. In addition, work has been done on different regional or cross-cutting initiatives:

- Technical guide for hydrological planning in the framework of integrated water resources management (IWRM) aimed at Latin America.
- Guide for wastewater treatment and sanitation projects planning.
- Support in the FCAS regional strategy on sector regulations. These regulations would include effluent discharges into the environment; effluent discharges to collectors, regulation of combined sewers and management of their drains, disposal of sludge and reuse of wastewater. In addition to Cuba, there are some countries that have also requested collaboration in the proposal or revision of their regulations, such as Haiti, Colombia, Honduras, Paraguay and El Salvador.

CEDEX has been hired by the Development Bank of Latin America (CAF) to provide technical assistance in the preparation of Argentina’s National Wastewater Treatment Plan. Under this contract, the centre has collaborated with the National Direction of Drinking Water and Sanitation of Argentina in the definition of objectives,



Above. Sotiel-Olivargas Dam. Prototype and physical model at 1/30 scale.

Below. Hydrodynamic study by numerical modelling of the Pálmaces Dam spillway.

in the framework of prioritization of actions, and in the estimation of actions costs and the proposal of regulations for water reuse.

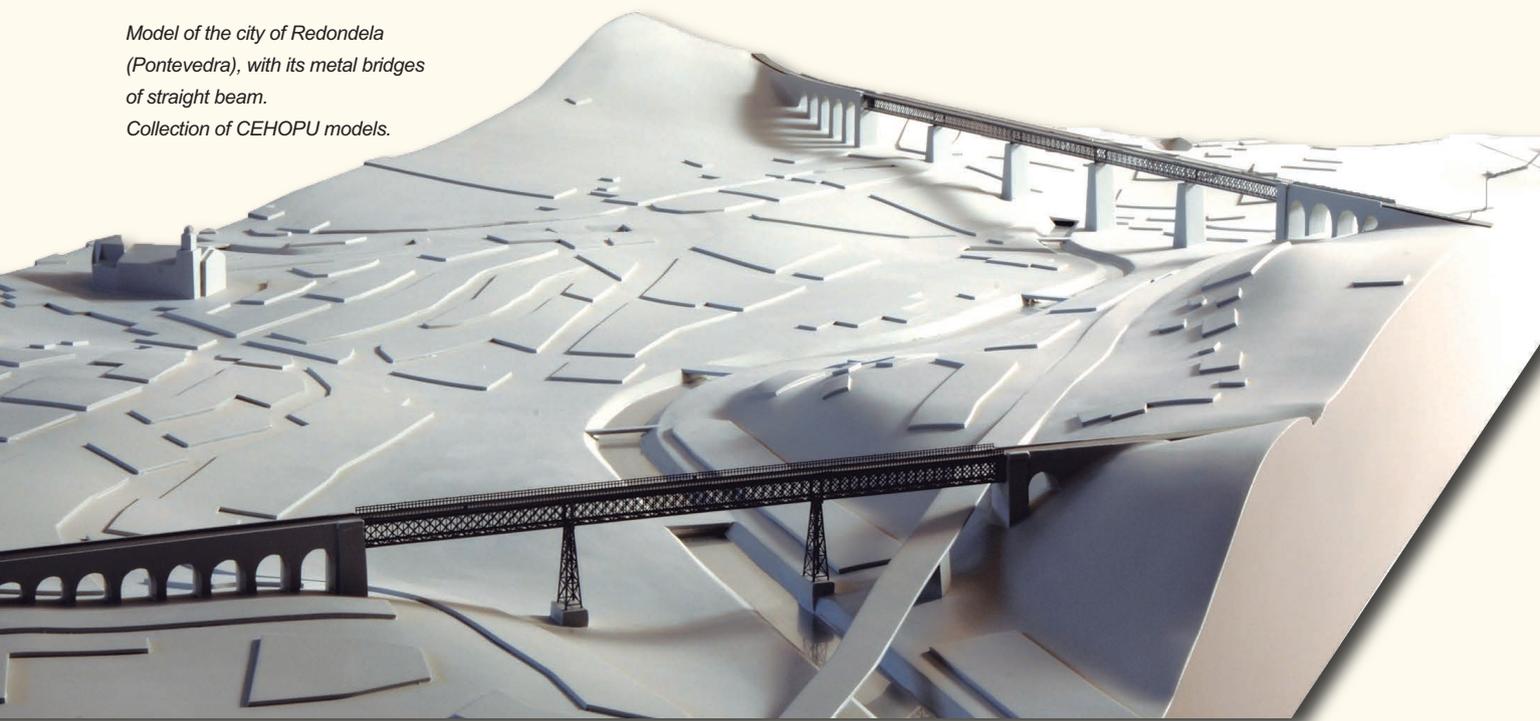
Technical assistance to the private sector:

- Hydraulic study by physical modelling of the Sotiel-Olivargas Dam spillway and bottom outlets (ACSA Obras e Infraestructuras SAU).
- Hydraulic study of the Pálmaces Dam spillway (FYSEG).
- Addendum to the hydraulic study by physical modelling of the right bank discharge facilities of the Angostura Dam, Perú (The Pampas of Sigwas Builder Inc. - Constructora las Pampas de Sigwas, SA).



CENTRE FOR HISTORICAL STUDIES OF PUBLIC WORKS AND URBAN PLANNING

*Model of the city of Redondela
(Pontevedra), with its metal bridges
of straight beam.
Collection of CEHOPU models.*



According to CEDEX's enabling statutes, it's for the Centre for the Studies of Public Works and Urban Planning (CSPWUP/CEHOPU) to research, study and disseminate the important historical heritage of public works in Spain.

Over more than thirty years the centre has carried out its activities through the organization of exhibitions, publications, participation in congresses, conferences, meetings, etc. In this extensive period of activity significant economic investment efforts have been made, not only in the creation of large exhibitions but also in the production of the Collection of Models of Public Works History, a unique collection of elements which, with a marked plastic and formal imprint, constitutes the most important representation of the evolution of the history of engineering, urban planning and public works, and its heritage in our country.

The continuous enrichment of the collection, the building-up of a specialized library with a pool of 8,000 items, and the creation of a graphic archive with more than 40,000 high-resolution reproductions, consisting of archival funds from around the world, are the result of a significant scheduled investment that will be an essential asset for the understanding of the vast work of civil engineering in Spain.

Also, the centre has managed both the deposit of the Torroja files and the Carlos Fernández Casado Archive, ceded by their owners for access to researchers from all over the world.

In 2019, the centre has continued its activity in the development of the different areas of activity in which its competences are organized. Thus, in relation to the program of traveling exhibitions, it was inaugurated in San Sebastian, within the activities of the Rezola Museum, the exhibition **Beyond the Arch. Bridges of Modernity**. This exhibition was open to the public from 20 June to 30 September, 2019.

This display is the continuation of an earlier one whose main theme is that of the Spanish bridges raised on arches. In this case, it is intended to make it known to the general public a set of accomplishments that serve as a common thread for the journey through an essential chapter of the history of engineering: the straight bridges without arches to support them. A wide typology stemming from new construction materials typical of a technological evolution that made them possible. Materials that required new techniques, technologies and typologies, and intrinsically connected with the idea of modernity in terms of scientific progress and advancement.



Medieval bridge of Jaca (Aragón).

To make this exhibition, pieces of the Model Collection of CEHOPU were used, along with new ones. In the showing, as mentioned, we trace the evolution of engineering in the nineteenth and twentieth centuries, from the suspension bridges, through the bridges of iron or steel beam, to those projected in reinforced concrete, without any doubt the material par excellence of the twentieth century. Alongside the models, a wide and evocative iconography is assembled, being the result of research in national institutions

Another CEHOPU exhibition that continues touring the Spanish geography since its opening in 2002, has been **Artifex. Roman Engineering in Hispania**, shown at the Science Museum of Valladolid from 11 July to 27 November, 2019, with remarkable success of public.

As part of the regular collaboration with the University of Valencia's Demetrio Ribes Chair, models have been borrowed for their showing at the exhibition **Rius per L'aire**, which opened on April 16 in Valencia's Museum of the City.

Research, study and content development

Not only is CEHOPU's researching the activity that supports its different projects, materialized in the exhibitions and publications that are defined in the following sections, but it also undertakes those ones leading to gain a better knowledge of the importance of the historical heritage of public works in Spain.

Likewise, an R&D&I action funded by the Ministry of Economy is allowing CEHOPU to take part, along with UNED, the Autonomous University of Madrid, the University of Barcelona, etc., in the project *Drawing of Engineers in the Modern Age: the Cities of the Mediterranean (XVI-XVIII Centuries)*, with participation in conferences, international congresses and publishing of books, one of them in preparation at the moment. Within this action Dolores Romero Muñoz has defended her doctoral thesis on September 23 about **Charles de Grunenbergh, a German Engineer in the Service of Philip IV and Charles II**. The qualification obtained has been Outstanding *Cum Laude*, with the proposal for the award of the Extraordinary Doctoral Award.

Dissemination of the history of public works

It's accomplished through the organization of exhibitions, publications and participation in congresses, conferences, etc.

a. New Exhibitions

Overlapping over time and in different organizational phases, it can be highlighted the following.

Santo Domingo de la Calzada. The Road Engineer

Based on the engineering works related to the Saint, on the Way of St. James, it was inaugurated on July 15 at the San Francisco Exhibition Centre in the Riojan town of the same name.



Detail of the tomb of Santo Domingo de la Calzada in the cathedral of the Riojan city, with the construction of the arch of a bridge.

Within the program of new exhibitions CEHOPU has been developing in recent years, it's planned to organize one in regard to urban planning during the period of the Enlightenment in Spain.

b. Itinerant Exhibitions

Currently, CEHOPU has 11 traveling exhibitions:

- *Iribarren. Engineering and Sea*
- *Artifex. Roman Engineering in Spain*
- *King Philip II of Spain. Artefacts and Machines*
- *Beyond the Arch. Bridges of Modernity*
- *Enlightenment Hydraulic Works*
- *Arch Bridges in Spain*
- *Ars Mechanicae. Medieval Engineering in Spain*
- *Ildefonso Sánchez del Río. The Power of a Legacy*
- *Félix Candela. The Achievement of Slenderness*
- *Carlos Fernández Casado. Engineer*
- *Torroja*

This exhibition has been organized by CEHOPU in collaboration with the Bishopric of the Diocese of Calahorra and La Calzada-Logroño, and has counted on specialists and researchers from the local parish.

CEHOPU provided the direction and coordination of the display, conjoint curation, and assembly and disassembly direction.

Thus, and organized in collaboration by CEHOPU, it glosses the beginning of the activity of Domingo García as the architect of bridges, hydraulic works and roads in the eleventh century, and as an urban planner. Today, the Saint is celebrated as Patron of the Corps of Engineers of both Public Works and those of Roads, Canals and Ports.

It's an initiation itinerary for some, cultural or patrimonial for others, in an encounter between the telluric and the theurgic.

The Enlightenment Urban Planning

CEHOPU has addressed the issue of urbanism from the very beginning. Undoubtedly, one of the most emblematic exhibitions of the more than 30 ones shown so far has been **The Spanish-American City. The Dream of an Order (1992)**.

This exhibition was a noteworthy event because, for the first time in Spain, urbanism was deemed as a fundamental element in the organization, articulation and management of very wide territories in Spanish America and the Philippines.

From July to December 2019, the exhibition **Artifex. Roman Engineering in Spain** was on display at the Museum of the City of Valladolid. Besides, the exhibition **Beyond the Arch. Bridges of Modernity** was on show at San Sebastian's Cemento Rezola Museum; and for the last quarter of the year it's intended to start a tour of **Spain in the Mediterranean. The Construction of the Space** throughout the autonomous communities of Murcia and Valencia.

The Origins of Reinforced Concrete in Spain

It's necessary to prepare a suitable itinerant package and the construction of some models.

Manila 1571-1898. West Encounters East

It's required to study the suitability of the panels and models in order to start its roaming.

Collection of models of History of Public Works

The collection is grouped by themes: metal bridges, concrete bridges, dams, arch bridges, straight bridges, artefacts and hydraulic machines, aqueducts, canals, port techniques, roofs, etc. Thematic exhibitions can be formed simply by preparing the written information in text and graphic panels with a small catalogue or brochure that illustrates them.

CEHOPU as a documentation centre

CEHOPU, in the exercise of its competences, and as part of its activities dedicated to preserving, studying and

disseminating the bibliographic heritage of public works, has held in its documentary centre the archive of projects by the engineer Eduardo Torroja and Miret.

In addition to these files, CEHOPU has the Graphic Archive for internal use resulting from the work carried out by the centre since its inception. It currently has more than 60,000 images and is intended to update it with new material collected in recent years, its cataloging, classification, inclusion in the database, signage and other necessary actions, as well as continuing the process of total digitization of the Graphic Archive.

CEHOPU Virtual Museum

Within the activities of CEHOPU, an initiative was launched to publicize the activity of the centre through communication via Internet. To this end, a website called the Virtual Museum is kept, being accessed from the ECOWAS website.

The museum shows more than twenty-five exhibitions held by CEHOPU since its creation in 1984. It also explains the contents, people involved, participating institutions and models related to such exhibitions, as well as evoking images of the first inauguration and the subsequent venues for which it has passed through.



Iconographic plan of the city of Milan by Antonio Lafrery, 1586.

Publications

In December 2019, it came out the facsimile edition of the undistributed book *Main Works of Reinforced Concrete Projected and Directed by Eduardo Torroja from 1926 to 1936*, a small jewel of very reduced print run, almost undistributed, written by Torroja as a gift to those who joined him in his homage to José Eugenio Ribera, the author of the prologue written just eight days before his death.



Images of the market of Algeciras, by Eduardo Torroja in the monograph *E. Torroja. His Works. 1926-1936*. Madrid, CEHOPU, 2019.





**KNOWLEDGE
TRANSFER**



KNOWLEDGE TRANSFER

KNOWLEDGE TRANSFER

Knowledge Transfer implemented in the CEDEX is framed within its Statutes and constitutes a transversal support unit that gives support to all its centres and laboratories, as well as to the professional sectors related to civil engineering, through the dissemination of scientific-technical knowledge and innovation.

Working areas are as follows:

- Professional Training
- Technical Publications
- Documentation and Library Network

PROFESSIONAL TRAINING

The Support Unit for Knowledge Transfer has continued working along the lines of previous years, in order to disseminate and transfer knowledge, managing its activities with efficiency and quality, all of which aimed at developing the continuous professional training of CEDEX staff, and transferring technology among the civil engineering professionals.

The global activity of unit has been divided into sectors of activity according to the following distribution:

Courses

Long-term courses (Master's Degree)

In the field of long-term courses, the **Master's Degree in Soil Mechanics and Geotechnical Engineering** has been held as a *National University of Distance Education*

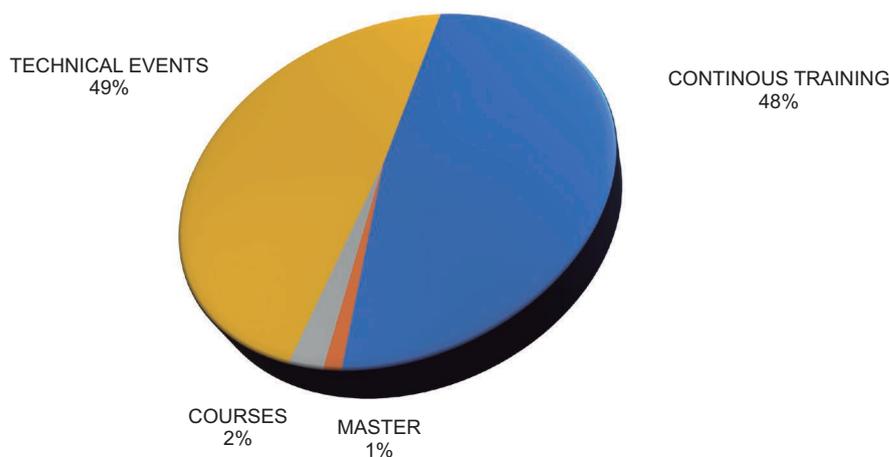
(UNED) degree. With 17 students, 9 of whom are Spanish and the rest from Latin American countries (Venezuela, Honduras, Bolivia and Chile), 560 teaching hours were given, including the preparation of a final master's thesis, in order to be part of the University's training offer, with an equivalence of 60 ECTS credits (European Credit Transfer and Accumulation System).

The master's degree, conceived by Professor José Antonio Jiménez Salas as an international course, has been held without interruption since the 1980s. In 2000 it acquired the category of Master's Degree, and since 2009, first with the Polytechnic University of Madrid (UPM) and currently with the UNED, it has a university status of its own.

Selective Courses for the Access to the Specialized Corps of the Public Administration and Professional Scales of Expert Technicians of Autonomous Public Agencies of the Ministries of Public Works, and for Ecological Transition and Demographic Challenge

The selective courses for access to the Ministry of Public Works' professional corps have been held at classrooms managed through the CEDEX Professional Training Programme, in collaboration with the Human Resources General Subdirectorate of the General Inspection of the Ministry of Public Works: Civil Engineers, Naval Engineers, and Professional Scales of Expert Technicians of Autonomous Public Agencies of the Ministry of Public Works, with a total of 119 students.

Other organizations have used the services of the Professional Training Program to organize tests



Training Distribution (Continuous training, Master Deg., Courses, Technical Events).



Leaflet presenting the Master's Degree in Soil Mechanics and Geotechnical Engineering 2019.

corresponding to different specialties, such as the Knowledge Test of the Port Service of Pilotage of the Directorate-General of the Merchant Navy.

National Course on Wastewater Treatment and Operation of Wastewater Treatment Plants

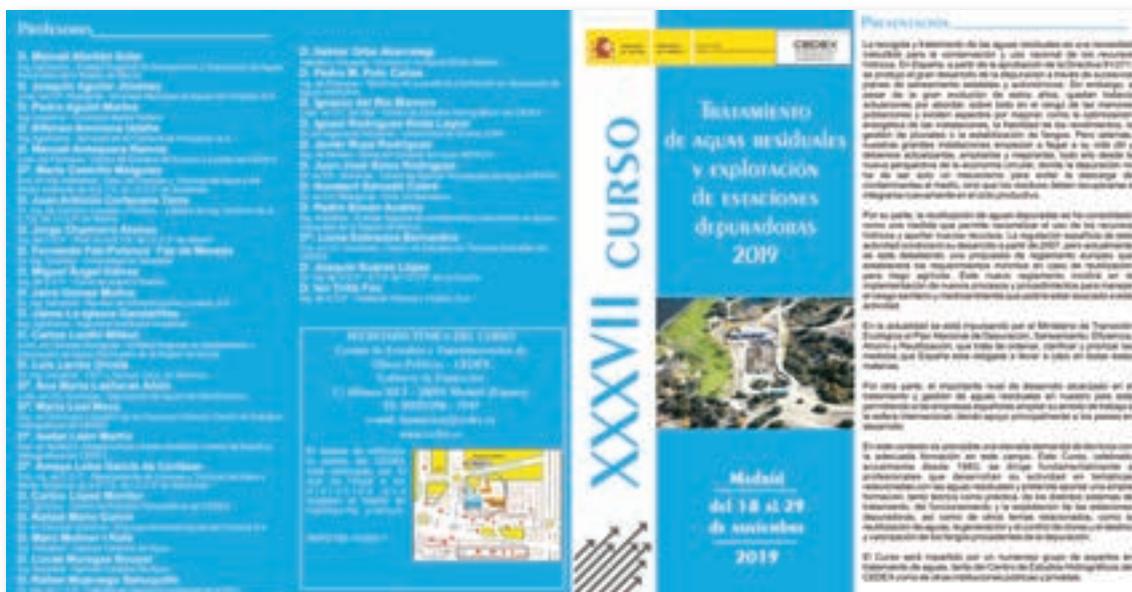
One of the most prestigious courses offered by CEDEX in the field of civil engineering is the *Course on Wastewater Treatment and Operation of Water Treatment Plants*, the XXXVII edition of which was held at CEDEX classrooms in November 2019.

This course, running since 1983, is aimed at professionals involved in wastewater treatment. 54 students have participated, all of them Spanish, except for one from

Costa Rica, one from Honduras and two from Cuba. The course consisted of 80 hours, including two visits to treatment plants.

Course of Coastal Engineering and Marine Environment

This course, organized by CEPYC, has consisted of 3 editions and counted on the participation of a total of 90 students. It was aimed at technicians from central and regional services of the Directorate-General for Sustainability of the Coast and Sea (DGSCM), and had the purpose to present general practical aspects of coastal engineering and environmental aspects related to coastal public works.



Leaflet presenting the XXXVII Course on Wastewater Treatment and Operation of Water Treatment Plants 2019.

Other courses

Among the activities of the unit, it should be underscored the organization of 41 events: meetings, training platforms, conferences and committees. In this respect, it's noteworthy the fact that numerous public and private institutions have chosen CEDEX's training facilities to hold such events, which have enjoyed high attendances.

Internal Training

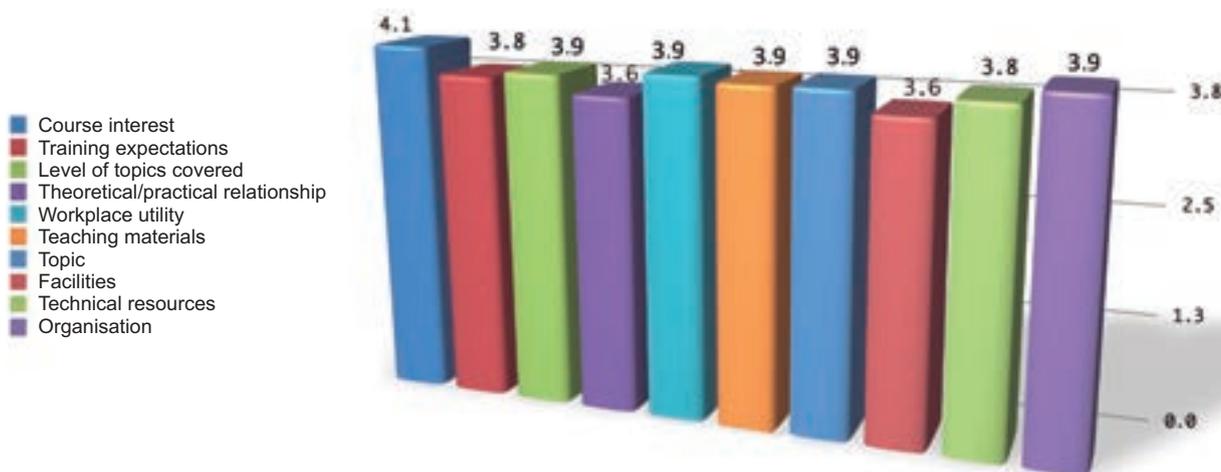
In regard to CEDEX's staff internal training, and focusing on the 2019 Continuing Professional Training Plan, new training actions have been developed as a result of the needs detected by the different centre managers, trade

unions organizations, workers' committees and public employees of the Agency.

Thus, this plan has become an important element to ensure the highest quality in terms of CEDEX's work outcome, not only in the administrative aspects but, especially, in the different specialized technical lines, on which a forefront organization such as CEDEX has a mission of vanguard. All this without forgetting the right of public employees to training and to professional and personal improvement.

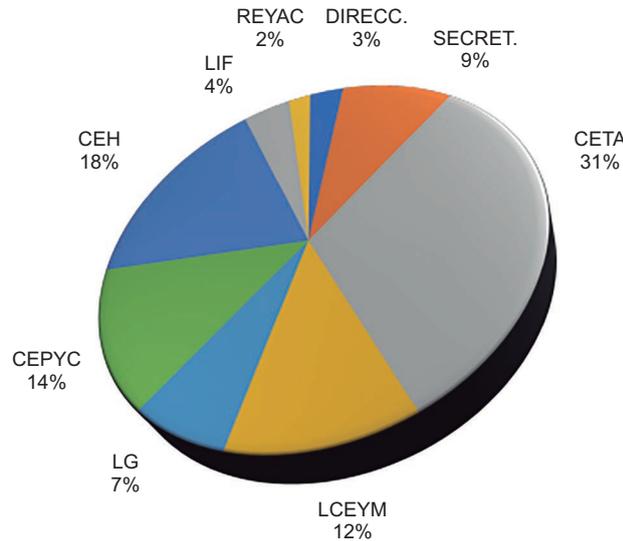
Thereby, a total of 40 courses have been held with a teaching schedule of 821 hours and 384 students (161 women and 223 men).

| CEDEX INTERNAL PROFESSIONAL TRAINING COURSES | | | |
|--|----------------|------------------|---------------|
| COURSE TYPE | COURSES NUMBER | ATTENDANT NUMBER | LECTIVE HOURS |
| Information and communication technologies | 11 | 116 | 192 |
| Languages | 8 | 87 | 276 |
| Specific and environmental posts | 11 | 89 | 216 |
| Occupational health | 10 | 92 | 137 |
| TOTAL | 40 | 384 | 821 |



The overall evaluation of courses by the attendees has been as shown above.

By participation of CEDEX's different centres and laboratories, the courses have been distributed as the following graph shows:



Program 4 of ESO + Private Sector Business

CEDEX has been collaborating with the Human Resources Department of the Ministry for Transports, Mobility and Urban Agenda (former Ministry of Public Works) in a program called 4th ESO + Private Sector Business, thanks to which 4th ESO students from the Community of Madrid high schools make a stay of between 3 and 5 days in some of the centres and laboratories. This mission is important for our institution and for the aforementioned ministry, for it's an opportunity for young people to learn about what we do and, hopefully, for bolstering future careers in civil engineering.

PUBLICATIONS

CEDEX, as an editorial unit of the Editorial Program of the Ministry for Transports, and within the General Publications Plan of the General State Administration (AGE), has continued in 2019 promoting the transfer of knowledge, and disseminating innovation processes in the fields of public works, civil engineering and environment. The 2019 editorial program has been completed with the edition of the following publications:

- *The Landscape in Engineering*
- *Cultural Heritage Forum of Public Works*



Images of the covers of CEDEX publications in 2019.



Covers of issues 193 and 194 of the *Ingeniería Civil* journal.

- Eduardo Torroja. *His Works. From 1926 to 1936*
- 2016-2017 *Gauging Yearbook*
- *Chemical Analysis Tests in Geotechnical Engineering. Use of Instrumental Techniques*
- *Technical and Scientific Activities, 2018*
- *XXXVII Course on Wastewater Treatment and Operation of Water Treatment Plants*

INGENIERÍA CIVIL JOURNAL

The journal *Ingeniería Civil* has published two issues (n° 193 and 194), instead of the regular 4 numbers per year, due to problems beyond the service of publications.

Both issues have been published on paper and digitally, being available in electronic format (PDF and XML / HTML) with free access through the CEDEX website (<http://cedex.es>).

DOCUMENTATION AND LIBRARY NETWORK

The Library Network, coordinated by CEDEX's Central Library, has continued supporting the Agency's research and technical assistance processes, providing the documentation required to its technicians so that these could carry out their work at CEDEX's centres and laboratories.

As in previous years, a single budget for the purchase of bibliographic resources has been used, centralized by the Central Library, which covered all the requests for books and other documentary resources without any restrictions. The Collective Catalogue of the Library Network has

increased by 609 records, reaching 130,965 titles and 165,575 volumes. The catalogue includes monographic titles, journals, maps, electronic resources and more than 9,500 technical reports produced by CEDEX.

The catalogue is of public access and available for consultation on this Internet address:
<http://vopac.cedex.es/opac>

Concerning subscriptions, as in recent years, no subscription or renewal of titles has been processed. Only those journals that are obtained through donation, in exchange for the *Ingeniería Civil* journal, or those edited by organizations or associations to which CEDEX belongs as a member, have been received.

This lack of subscriptions has been supplemented by subscribing to the "article choice" online that enables the downloading of articles from Elsevier's Science Direct database, which gives access to any article from a range of more than 3,800 titles of its journal collection. Interlibrary loan has been used to obtain articles from other publishers.

WOS (Web of Science) subscription to databases has also been renewed through FECYT. By accessing these databases, the technicians and researchers have been able to know the published bibliography on their areas of interest, the impact obtained from the articles they have published in international indexed journals, and the citations of those articles; as well as to search for interrelated articles and receive content alerts on their areas of interest and research.



View of the Library of CEDEX's Central Laboratory of Structures and Materials.

As for customer service, an increase in digital requests continues being detected in relation to face-to-face applications. A significant number of requests are made by email, and are also handled by the same system, digitalizing those requests which, owing to their size, can be sent by e-mail.

Only CEHOPU Library and the Torroja and Fernández Casado Archives have had an increase in on-site users, mainly due to the special characteristics of this documentation, which in most cases entails on-site attendance.





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