

CEDEX

TECHNICAL AND SCIENTIFIC ACTIVITIES | 2020



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AND SCIENTIFIC ACTIVITIES

2020



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FOREWORD

ÁUREA PERUCHO MARTÍNEZ
Director of CEDEX



The Centre of Studies and Experimentation of Public Works, O.A. and M.P. (CEDEX), is statutorily defined as one of the public agencies provided for in Article 98 of *Law 40/2015, of October 1, on the Legal Regime of the Public Sector*, attached organically to the Ministry for Transports, Mobility and Urban Agenda (MITMA), through the Secretary of State and, in turn, functionally to both that department, and the Ministry for Ecological Transition and the Demographic Challenge (MITERD), in the sphere of their respective competences.

In my capacity as director, I have the honor of presenting this report on technical and scientific activities, which reflects the work carried out by this agency in 2020, a year characterized by the difficulties imposed by Covid-19.

First of all, I'd like to acknowledge the work accomplished during this year by Mr. Pedro Saura García and Mr. José Trigueros Rodrigo, former president and director, respectively, of the agency, and to point out that my appointment as head of CEDEX took place at the beginning of 2021. Therefore, these lines stem from my deepest respect for the good work passed on to me, and the illusion with which I intend keep on and bolster up the thriving of the agency.

The activity of CEDEX in 2020 reflects the development of the planning contained in its *Strategic Plan for 2020-2022*, whose main objective revolves around the alignment of technical assistance, R&D&I and knowledge transfer –among the main functions undertaken by CEDEX– with the policies promoted by MITMA and MITERD. It's important to highlight the significant role that the framework defined by the *2030 Agenda* and the *Sustainable Development Goals* has played in the definition of this plan and, more specifically, in the *2020 Annual Program*. Thus, the agency has consolidated its reference position as the technological arm of both departments in strategic aspects such as digitalization, innovation in mobility,

or the specific promotion of innovation understood as applied research for the solution of the complex multidisciplinary problems of modern civil engineering, internalizing the concept of sustainability in its work dynamics.

Within the framework of the Ministry for Transports, Mobility and Urban Agenda, the range of activities described in this report underlines the consolidation of CEDEX as an indispensable actor capable of contributing to the implementation of the three main political lines of work for this department in 2020. Firstly, assistance in defining and launching the *Recovery, Transformation and Resilience Plan*. Secondly, support for the implementation of the *Safe, Sustainable and Connected Mobility Strategy*. And thirdly, support, support through specific actions for the materialization of the three vectors of the transport and mobility policy promoted by the department: the growth of urban areas and the resolution of the associated rural challenges; the reduction of all types of emissions and, in particular, their effect on climate change; and, the internalization of digitalization tools as an inherent part of the operating dynamics in the resolution of problems associated with civil engineering and the environment.

As for the Ministry for Ecological Transition and the Demographic Challenge, CEDEX has included its 2020 activities within the *Strategic Framework for Energy and Climate* approved by the Spanish government in 2019. This framework is defined by four major vectors of sectoral change: firstly, the spirit contained in the *Climate Change and Energy Transition Law* in line with the United Nations resolutions, and the obligations assumed by the Parties to the *2015 Paris Agreement* on climate change; secondly, and under the same strategic orientation as the aforementioned law, the *National Integrated Energy and Climate Plan* (PNIEC); thirdly, the *Long-Term Decarbonization Strategy* (EDLP 2050), which paves the way to achieve climate neutrality by 2050; and fourthly, the

Just Transition Strategy, which aims to optimize the results of the ecological transition for employment.

In this way, the agency has strengthened its leadership as the technological mainstay of the General State Administration in its three main categories of action –technical assistance, R&D&I and knowledge transfer–, in the various thematic areas concerning civil engineering and environment. A good example of this is the thirty or so relevant projects described in this report under the subcategories of studies, projects and plans; modelling and modulations; inventories and information systems; controls, monitoring and evaluations; tests, trials,

calculations and analysis; methodological frameworks, developments and regulatory transpositions; and digitalization.

In a year marked by the suffering caused by Covid-19, which has changed our lives, I'd like to highlight the value of the high-quality services provided by CEDEX, which, thanks to its human capital, is a benchmark for learning, experience, commitment, and clarity of objectives to act in the public interest.

Finally, I'd like to make a special mention to the colleagues who have left us during this period, and to those who have suffered most the consequences of this pandemic.



Centro de Estudios Hidrográficos

Centro de Estudios de Puertos y Costas

Centro de Estudios Históricos de Obras Públicas y Urbanismo

PRESIDENCIA

Centro de Estudios del Transporte

DIRECCIÓN

SECRETARÍA

CEDEX

Laboratorio de Interoperabilidad Ferroviaria

TRANSFERENCIA DE CONOCIMIENTO

Centro de Estudios de Técnicas Aplicadas

Laboratorio de Geotecnia

Laboratorio Central de Estructuras y Materiales

ABOUT US. KEY FIGURES



ASSIGNMENTS AND FUNCTIONS

The Centre for Studies and Experimentation in Public Works (CEDEX), O.A., M.P., 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 of Transport, Mobility and Urban Agenda, through the Secretary of State of Transport, Mobility and Urban Agenda, and with functional dependence of the Ministry of Transport, Mobility and Urban Agenda (MITMA) and the Ministry for Ecological Transition and Demographic Challenge (MITERD), 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 is 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 of Transport, 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&I 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

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. The Council is composed of the following members:

Presidency

Secretary of State of Transport, Mobility and Urban Agenda

Vice Presidency

Secretary of State for the Environment of the Ministry for Ecological Transition and the Demographic Challenge

Members for the Ministry of Transport, Mobility and Urban Agenda

Under Secretary of Transport, Mobility and Urban Agenda
 General Directorate of Roads
 General Directorate of Merchant Marine
 General Directorate of Housing and Land
 Presidency of the State Ports Public Entity
 Directorate of the State Agency for Railway Safety
 Directorate of CEDEX

Members for the Ministry of Ecological Transition and Demographic Challenge

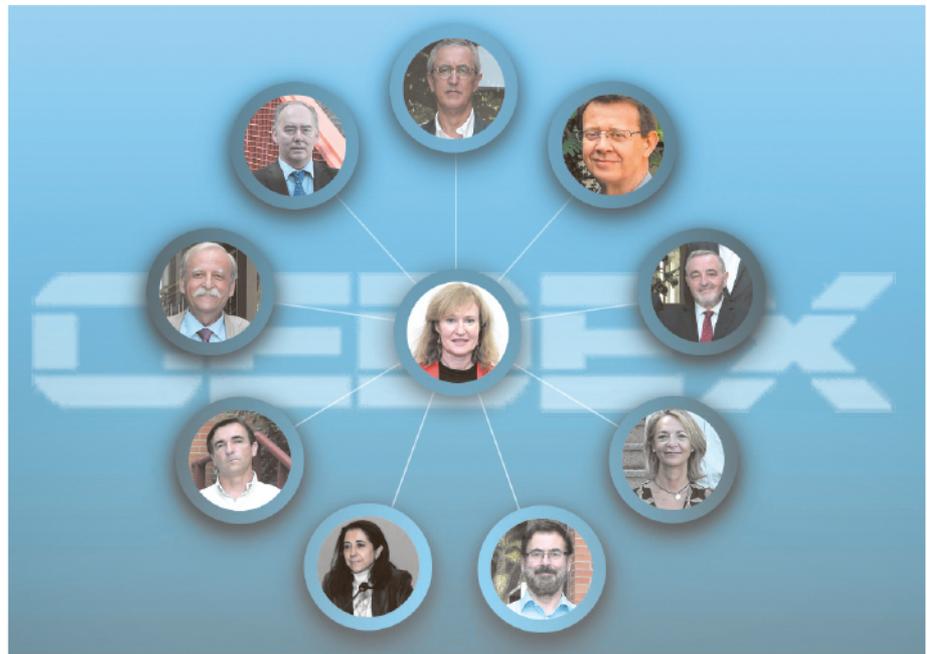
Under Secretary for Ecological Transition and Demographic Challenge
 General Directorate of Water
 General Directorate of the Coast and the Sea

General Directorate of Environmental Quality and Assessment
General Directorate of Biodiversity, Forests and Desertification
General Directorate of the Spanish Climate Change Office
Members for the Ministry of Science and Innovation
General Directorate of Research Planning

Secretary

Directorate of the Center for Hydrographic Studies of CEDEX

STEERING COMMITTEE



CEDEX Steering Committee

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

The President

Directorate of CEDEX

Members

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

Secretary

The Head of External Relations and Commercial Activities

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.

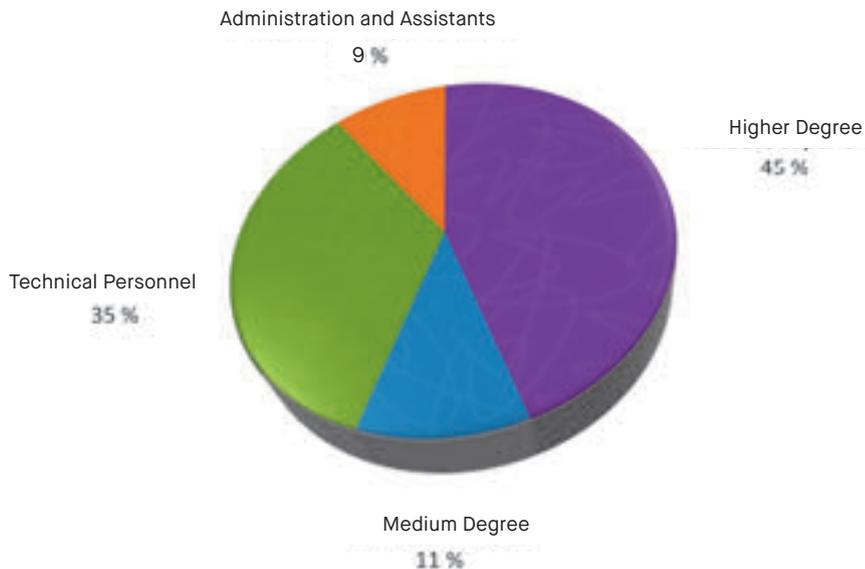
An additional characteristic note is the multidisciplinary integration in the CEDEX teams of professionals with different backgrounds: engineering sciences and other technical activities, earth sciences and basic science, which provide complementary visions in the study of increasingly complex issues 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.

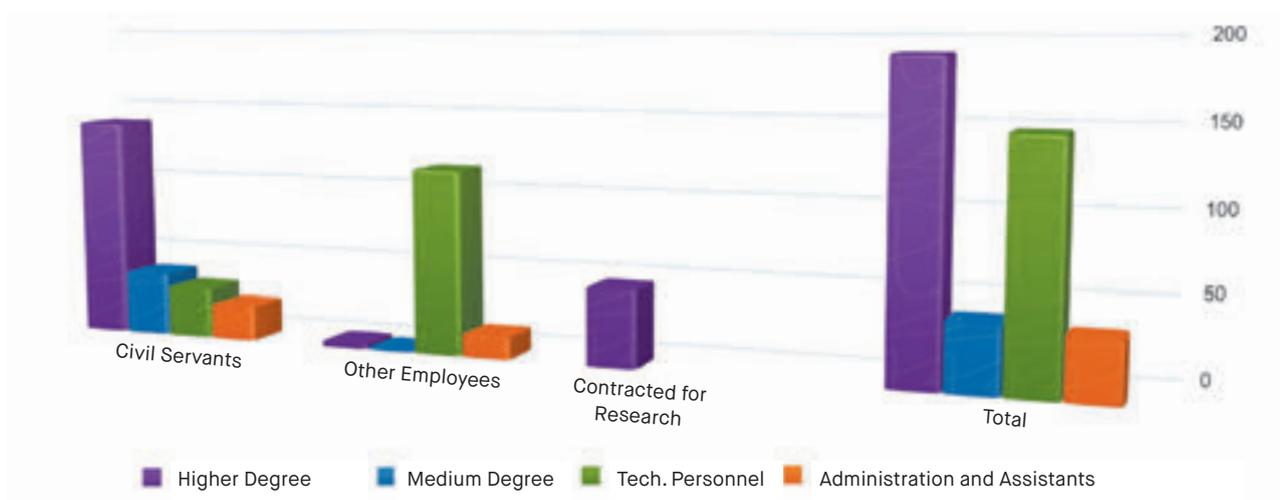
PERSONNEL BY CATEGORY AND QUALIFICATION ON 31-12-2020

| | | Civil Servants | Other Employees | Contracted for Research | Total | % |
|-------------------------------|---------------|----------------|-----------------|-------------------------|------------|-------------|
| Degree | Higher Degree | 140 | 3 | 48 | 191 | 46% |
| | Medium Degree | 40 | 1 | 0 | 41 | 10% |
| Technical Personnel | | 32 | 116 | 0 | 148 | 35% |
| Administration and Assistants | | 22 | 24 | 0 | 36 | 9% |
| TOTAL | | 234 | 134 | 48 | 416 | 100% |

PERSONNEL BY QUALIFICATION



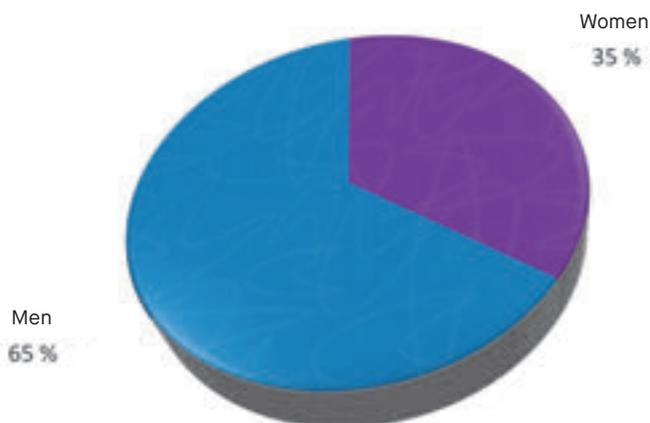
PERSONNEL BY CATEGORY AND QUALIFICATION



PERSONNEL BY GENDER ON 12-31-2020

| | | Women | | Men | | Total |
|-------------------------------|---------------|------------|------------|------------|------------|------------|
| Degree | Higher Degree | 79 | 41% | 112 | 59% | 191 |
| | Medium Degree | 12 | 29% | 29 | 71% | 41 |
| Technical Personnel | | 40 | 27% | 108 | 73% | 73 |
| Administration and Assistants | | 16 | 44% | 20 | 56% | 56 |
| TOTAL | | 147 | 35% | 269 | 65% | 416 |

GENDER DISTRIBUTION

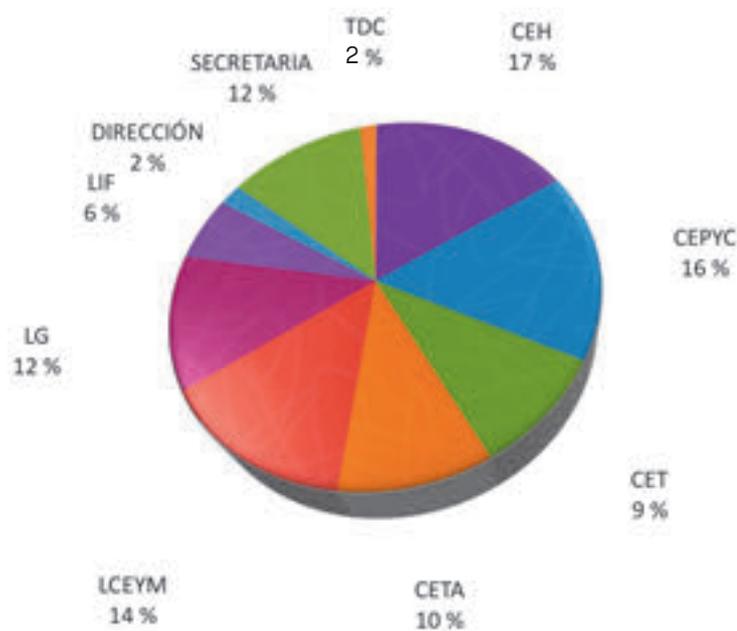


PERSONNEL BY CENTRE AND CATEGORY ON 31-12-2020

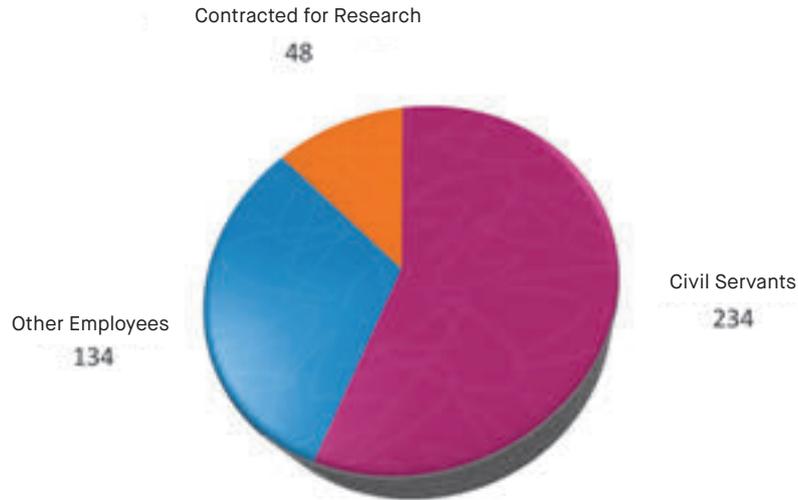
| | CEH | CEPYC | CET | CETA | LCEYM | LG | LIF | DIREC. | SECRE. | TDC | TOTAL |
|--------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|-----------|----------|------------|
| Civil Servants | 42 | 38 | 19 | 25 | 28 | 23 | 16 | 5 | 34 | 4 | 234 |
| Other Employees | 20 | 21 | 13 | 9 | 27 | 21 | 4 | 2 | 15 | 2 | 134 |
| Contracted for Research | 9 | 8 | 6 | 8 | 5 | 7 | 4 | 1 | 0 | 0 | 48 |
| TOTAL | 71 | 67 | 38 | 42 | 60 | 51 | 24 | 8 | 49 | 6 | 416 |

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 BY CATEGORY



MOST RELEVANT SELECTIVE PROCESSES CALLED IN 2020

Scale of Higher Expert Technicians from Autonomous Agencies

Posts offered for CEDEX:

- Autonomous Public Agencies of the Ministry of Public works: Resolution of 24 September 2020, BOE of 1 October 2020. It corresponded to the Public Employment Offer (OEP) of 2019: 11 posts were offered for free shift and 6 for internal promotion. Of these, 3 posts were programmed for the free shift for CEDEX: 1 post for CEPYC, 1 post for LG and 1 post for CET; and 2 for internal promotion: 1 post for LCEYM and 1 post for CEHOPU. However, the resolution of 24 September 2020 was suspended as a result of Ruling n° 1679/2020 of 4 December 2020 of the Fourth Section of the Contentious-Administrative Chamber of the Supreme Court, which annulled the specific basis 4.1. MITMA has not communicated the final decision in this regard.
- Autonomous Public Agencies of the Ministry of the Environment. Resolution of 12 February 2020, BOE of 18 February 2020. 98 posts were offered for the free shift corresponding to the 2018 and 2019 OEP, and 20 post for internal promotion corresponding to the OEP of 2018. Regarding the aforementioned 2018 and 2019 OEPs, from the 2018 OEP, 3 free shift positions were requested for CEDEX (1 post for CEH and 2 posts for CETA) and 2 internal promotion (both for CETA), and 5 free shift were requested for the 2019 OEP. It is not known how many post will be allocated to CEDEX.

Corps of Civil Engineers of the State

Resolution of 21 September 2020, BOE of 28 September. Corresponds to the 2019 OEP and 58 posts were offered for free access and 4 for internal promotion. For the 2019 EPO, 11 posts were requested for

CEDEX for free access. It is not known how many posts will be allocated to CEDEX.

Corps of Technical Engineers for Public Works

Resolution of 26 August 2020, BOE of 7 September. Corresponds to the OEP of 2019 and 44 posts were offered for free access and 2 for internal promotion. For the OEP of 2019, 1 post for free access was requested for CEDEX. It is not known if any posts will be allocated to CEDEX.

LABOUR RIGHTS AND POLICIES

Social dialogue and collective bargaining

The Agency participates in the different negotiating bodies in the Ministry of Transport, 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 March 22, 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: 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: in 2020, the workforce had 18 employees with some degree of disability:
 - Degree of disability 1 (>33% and < 65%): 12 (6 civil servants and 6 other employees).
 - Degree of disability 2 (degree of disability 1 with assistance): 0.
 - Degree of disability 3 (=> 65%): 6 others employees.

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.



- Remote work programme, set up in response to the COVID-19 situation to make it easier for employees to care for their children and elderly dependants.

Social action

The budget for Social Assistance in 2020 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 183, corresponding to 265 grants processed and materialized in 262 grants granted.

Of these, the most demanded have been:

- Studies for the children, € 35,123 to cover 156 grants.
- Employee health treatments, with € 9,974 for 41 grants.
- Transport, with € 11,911 for 42 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.
- Legionella control.

Preventive activities

The main preventive activity for the protection of all the Agency's personnel has been carried out through health surveillance by means of medical examinations.

Due to the global health crisis caused by the SARS-CoV-2 virus, extraordinary measures were approved for the exceptional protection of employees to minimise the risk of contagion. In particular, a telecommuting programme was set up and a user manual and a document on occupational risk prevention (PRL) measures for telecommuting were drawn up. Some courses were also organised on teleworking in PRL, COVID-19, emotional management and the return to the new normal.

In order to guarantee the safety of workers, due to the work carried out by external companies on CEDEX premises, coordination protocols were drawn up to mitigate the risk that could arise from the presence of personnel belonging to external organisations.

Security

Through the Agency's intranet, information was provided on relevant prevention issues:

- Information to avoid pandemic fatigue.
- Good preventive practices, new developments with regard to the coronavirus.
- Evaluation of CEDEX workplaces against exposure to SARS-CoV-2.
- Influenza vaccination 2020 campaign.
- Medical examination 2020 campaign.
- Action protocol for on-site reincorporation into working life.
- Protocol for users of CEDEX vehicles.
- Protocol for field work.

In addition, the following were carried out:

- Risk assessments of new staff.
- Preventive planning of work centres.
- Investigation of occupational accidents with and without sick leave.
- Attendance at meetings of the Health and Safety Committee and those convened by MITMA.
- Resolution of consultations made by the centres and trade union delegates.

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.



Sustainable mobility

Three wall-mounted charging devices with double sockets have been installed in the garage of the CETA building to provide service to electric vehicles and plug-in hybrid vehicles, both official and private for CEDEX staff. The fleet of official vehicles has been renewed with the acquisition of 3 Nissan Leaf electric vehicles and 4 Mitsubishi Outlander hybrid electric vehicles. Both actions contribute to the deployment of electric mobility while at the same time helping to reduce atmospheric emissions and other pollutants.

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

In relation to the Environmental Management System, the Centre for Studies and Experimentation in Public Works was accredited through the EN ISO 14001:2004 Standard between 2009 and 2017 in all its centres.

The certification of compliance with the requirements laid down in the UNE-EN ISO 14001: 2015 Standard has been assessed and is maintained until 17 April 2021 with certificate number: ES09/6695. This is a multi-site certificate that includes all CEDEX centres.

The quality activities carried out in the different centres and laboratories of the Agency include those listed in the following table.

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).
- 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.

| Unit undergoing a Quality Certification or Accreditation Audit Process | Certification Standard: Quality System | Certification or Accreditation issuing body |
|---|--|---|
| Central Laboratory for Structures and Materials (LCEYM) Activity: Tests Accreditation n°: 82/LE688 - Metallic Materials | UNE-EN ISO/IEC 17025:2017 | National Accreditation Body (ENAC) |
| Center for Applied Techniques Studies (CETA) Activity: Tests Dossier 82/LE1955 - Radiological Protection | UNE-EN ISO/IEC 17025:2018 | National Accreditation Body (ENAC) |
| Railway Interoperability Laboratory (LIF) Activity: Tests Dossier 465/LE1003 – Railway and its components | UNE-EN ISO/IEC 17025:2019 | National Accreditation Body (ENAC) |
| Centre for Hydrographic Studies (CEH) Water Environment Area of the Water Quality Laboratory | UNE-EN ISO 9001:2015 | System Certifiers SGS |

CODES OF CONDUCT

Specific ethical codes available to the Agency, following the protocols of 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, MITMA citizen service.
- 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 Informa*, 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 2020 REVENUE BUDGET | | | |
|--|-------------------|-------------------|-------------|
| SECTION | FINAL BUDGET | RECOGNIZED RIGHTS | EXECUTION % |
| 3. Fees, public prices and other incomes | 12.914.000 | 4.732.529 | 37% |
| 4. Current transfers | 15.298.811 | 15.398.629 | 101% |
| 5. Equity incomes | 1.550 | 614 | 40% |
| 7. Capital transfers | 990.000 | 996.935 | 101% |
| 8. Financial assets | 3.557.750 | 15.034 | 0% |
| TOTAL INCOME BUDGET | 32.762.111 | 21.143.740 | 65% |

| EXECUTION OF THE 2020 EXPENSE BUDGET | | | |
|--------------------------------------|-------------------|-------------------|-------------|
| SECTION | FINAL BUDGET | RECOGNIZED RIGHTS | EXECUTION % |
| 1. Personnel expenses | 20.806.340 | 18.810.248 | 90% |
| 2. Goods and services | 5.502.122 | 3.662.342 | 67% |
| 4. Current transfers | 3.155.800 | 3.085.421 | 98% |
| 6. Investments | 3.259.529 | 2.057.230 | 63% |
| 8. Financial assets | 38.320 | 4.800 | 13% |
| TOTAL EXPENSE BUDGET | 32.762.111 | 27.620.041 | 84% |

INCOME PER ACTIVITY DISTRIBUTED BY CENTRES AND RECIPIENTS YEAR 2020 (EXCLUDING VAT)

| | CEH | CEPYC | GET | CETA | LCEYM | LG | LIF | TDC | Total | Recipient / Total % |
|---|------------------|------------------|----------------|----------------|----------------|----------------|----------------|----------------|------------------|---------------------|
| Ministry of Transport, Movility and Urban Agenda* | 0 | 762.560 | 900.710 | 15.000 | 404.089 | 60.000 | 0 | 231 | 2.142.589 | 28% |
| Ministry for Ecological Transition and the Demographic Challenge* | 3.234.147 | 560.552 | 0 | 96.880 | 0 | 0 | 0 | 0 | 3.891.579 | 51% |
| Rest of the Administration* | 216.514 | 0 | 1.000 | 353.529 | 63.278 | 0 | 0 | 47 | 634.368 | 8% |
| Nacional Clients | 34.065 | 0 | 96.822 | 85.128 | 136.481 | 42.972 | 165.827 | 122.382 | 683.677 | 9% |
| Internacional Clients | 35.376 | 80.416 | 0 | 0 | 0 | 14.029 | 127.795 | 48.049 | 305.664 | 4% |
| TOTAL | 3.520.101 | 1.403.528 | 998.532 | 550.537 | 603.848 | 117.001 | 293.622 | 170.709 | 7.657.877 | 100% |
| % CENTRE/TOTAL | 46% | 18% | 13% | 7% | 8% | 2% | 4% | 2% | 100% | |

* Administration's own tool.

Note: The table shows the total fees recognised for the activity carried out by CEDEX centres and laboratories during the financial year 2020.

CEH (Centre for Hydrographic Studies)
 CEPYC (Centre for Ports and Coasts Studies)
 GET (Centre for Transport Studies)
 CETA (Center for Applied Techniques Studies)
 LCEYM (Central Laboratory for Structures and Materials)
 LG (Geotechnical Laboratory)
 LIF (Railway Interoperability Laboratory)
 TDC (Knowledge Transfer)

SITUATION BALANCE SHEET

| ASSETS | 2020 | 2019 |
|--|-------------------|-------------------|
| NON-CURRENT ASSETS | 71.662.006 | 72.857.118 |
| Intangible fixed assets | 245.759 | 246.098 |
| Industrial and intellectual property | 1.625 | 1.950 |
| Computer applications | 244.134 | 244.148 |
| Tangible fixed assets | 71.412.847 | 72.603.264 |
| Lands | 28.515.852 | 28.515.852 |
| Constructions | 31.198.684 | 32.298.200 |
| Other tangible fixed assets | 10.902.559 | 10.993.461 |
| Fixed assets in progress and prepayments | 795.752 | 795.752 |
| Long-term financial investments | 3.400 | 7.755 |
| Credit and Debt securities | 3.400 | 7.166 |
| Other financial investments | 0 | 589 |
| CURRENT ASSETS | 17.445.867 | 25.797.966 |
| Trade and other receivables | 15.325.984 | 21.916.951 |
| Receivables from management operations | 11.840.430 | 18.927.392 |
| Other receivables | 69.636 | 233.668 |
| Receivable from public authorities | 3.415.918 | 2.755.891 |
| Long-term financial investments | 3.295 | 9.174 |
| Credit and Debt securities | 2.706 | 9.174 |
| Other financial investments | 589 | 0 |
| Adjustments due to accrual | 289,44 | 289 |
| Cash and cash equivalents | 2.116.298 | 3.871.551 |
| Cash | 2.116.298 | 3.871.551 |
| TOTAL ASSETS | 89.107.872 | 98.655.083 |

| EQUITY AND LIABILITIES | 2020 | 2019 |
|---|-------------------|-------------------|
| EQUITY | 88.110.070 | 95.486.428 |
| Contributed equity | 84.251.752 | 84.251.752 |
| Generated equity | 3.831.990 | 11.190.289 |
| Profits or losses from previous years | 11.179.806 | 13.587.704 |
| Profit or loss for the year | -7.347.816 | -2.397.416 |
| Other capital increases pending imputation to income | 26.328 | 44.387 |
| CURRENT LIABILITIES | 997.802 | 3.168.655 |
| Current payables | 249.359 | 1.491.175 |
| Other receivables | 249.359 | 1.491.175 |
| Trade and other payables | 748.443 | 1.676.510 |
| Payables from management operations | 92.416 | 491.047 |
| Other payables | 215.860 | 818.136 |
| Public Administrations | 440.167 | 367.328 |
| Adjustments due to accrual | 0 | 970 |
| TOTAL EQUITY AND LIABILITIES | 89.107.872 | 98.655.083 |

CENTRE FOR TRANSPORT RESEARCH





Considering the mobility restrictions imposed by the health authorities in 2020 and their influence on the performance of working activities, as those related to road management were established as essential activities, such as the auscultation of roads or the tasks of the Road Materials Laboratory, did not experienced a significant stoppage, which have resulted in the activities of the Transport Research Centre not declining and having remained substantially similar to those of previous years.

On the other hand, new works have been added to the usual activities carried out in the Transport Research Centre of CEDEX, such as responding to the new services that the transport network and, specially, the road network has to address, in order to provide the service and to correctly meet the demands arising from the gradual incorporation of the connected vehicle into the traffic flow or from other technological advances of the vehicle, which must have their corresponding response in the performance of the road network, adapted to their needs.

Thus, the digitalization of the information on road parameters that had already been done in the framework of pavement monitoring, maintenance and management tasks has been aimed at responding to provide road information to connected vehicles.

Likewise, the deadlines set to achieve transport decarbonisation have also launched another line of work focused on studying how vehicles can contribute to this zero emissions targets. It means that road infrastructure also has to adapt to allow the circulation of vehicles powered by energies that do not involve the use of fossil fuels, or even fuels from renewable energies that do not generate greenhouse gases emissions. It has to be taken into account that there are several possible ways of approaching this objective, each with its advantages

< In the foreground, a metal safety barrier, which includes a post, a spacer and a W-beam.

and disadvantages, its supporters and its detractors. Therefore the study of these options with objectivity and impartiality -from the point of view of the Spanish roads reality- has been another of the activities undertaken in 2020.

It should also be borne in mind that because of the long periods involved in the design, construction and operation of road projects, any consideration must be assessed in views of a changing climate context. In this context, adverse phenomena can be more extreme and, consequently, the corresponding initiatives must be adapted to the effects of these phenomena and must contribute to their mitigation, if possible.

This implies that new lines of research have to be undertaken. For example, there is a need to define the characteristics of new materials and new structures built with these materials with the purpose of providing a satisfactory response to the new situations that might arise in views of climate change. Moreover, these materials and structures should be capable of adapting to these new situations without collapsing.

Within this general context, the most relevant activities carried out during 2020 could be summarized as follows:

Regarding the CLARITY project, which has already presented in detail in another section, it should be noted that it has successfully fulfilled the planned objectives. It is expected that the methodology proposed within the project, that supports the identification of climate change impact on transport infrastructures, can be implemented in other road transport networks (beyond the pilot case that was located in a section of the A-2 highway in the province of Guadalajara between the km. 62 and km 135).



The digitalisation of the information on road parameters has been aimed at responding to provide road information to connected vehicles.

Pavement with an alligator cracking type damage, which denotes that it has exceeded its resistance to fatigue or its bearing capability.



FENIX test specimen for the study of the properties of bituminous mixtures.



Indeed, the web based tool that has been developed, the know-how acquired in field of climate change prediction models and other issues related to this project allow the methodology to be applied to new sections of the road network or other land transport infrastructures. The final purpose is assessing -in a methodical and systematized way- transport infrastructures vulnerability to climate change. This means that the termination of CLARITY does not imply the end of this research line, it rather opens a new path of knowledge of the behavior of roads in the face of climate change, which is expected to be addressed in successive exercises.

With the objective of supporting climate change impacts assessments on roads, six meteorological stations have been built and are being operated. Specific data on temperatures, radiation, humidity, etc. will be extracted, due to the special impact on the road infrastructure and road traffic of these climate variables. This data will complement the information on meteorological variables provided by the corresponding services (meteorological agencies) and will be used to attend the specific requirements of road transport operators.



Six meteorological stations have been built and are being operated, from which concrete and specific data are collected, that have a special impact on the road and traffic.

Since a permanent weigh-in-motion (WIM) station was implemented within the REPARA 2.0 Project, in which CEDEX took part, aimed at knowing the traffic loads, the information generated by this equipment has been continuously collected and processed, and the way to set up a network of permanent WIM stations is being studied, from which the necessary information could be extracted to implement initiatives aimed at payment per use.

Related to circular economy and non-conventional materials utilization in road construction, the seventh monitoring campaign on the instrumented section on Ma-30 road, in Mallorca, has been carried out in 2020. In this road, several sensors were collocated and this allows us to monitoring and evaluate the performance of solid urban waste used on road construction mixed with cement. The repeated monitoring of this pavement and the experience that can be obtained from these works allow consolidating the knowledge about the possibilities of this material and the circumstances that advise or discourage its use in road projects or other transit routes.



“Big bags” of NFVU (tyres at the end of their service life) waiting for the manufacture of a bituminous mixture with crumb rubber.

Regarding the use of crumb rubber from end-of-life tires (NFVU), CET has participated jointly with the Demarcación de Carreteras de Aragón in the construction project of the Ebro Highway (A-68), in which two test sections were built: A first one comprising a bituminous mixture with NFVU crumb rubber incorporated by the so-called wet process, and a second one with the same material previously predigested. The aim for this test and the instrumentation placed is to compare the advantages of either way of incorporating the crumb rubber, firstly during the road construction phase but also in the subsequent behavior of the pavement.

This action has been carried out on the Accelerated Pavement Test Track of the CET with identical types of pavement for knowing the performance of these road sections by applying 50.000 load cycles.

Related to road auscultation, the last task commissioned by DGC has been continued which goals are to monitor, check and supervise compliance with the value of indicators made in the first generation concession contract of the RCE. From this centre, the indicators obtained are related to structural capacity and safety and comfort conditions, and the measured parameters are skid resistance, roughness index (IRI), deflections, cracking and other distresses.

In another área, a significant work has been carried out in the field of evaluating road projects according to sustainability criteria, both in their design and construction phases, as well as in their operation, specifically referring to the application of the Life Cycle Assessment (LCA) and Life Cycle Cost Analysis (LCCA), as a tool for evaluating actions in search of their efficiency in the consumption of resources, raw materials and energy, and in the generation of

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From this centre, the indicators on the structural state and safety and comfort conditions on the managed roads are monitored: skid resistance, road surface roughness (IRI), structural capacity (deflections), cracking and other distresses.



SCRIM equipment measuring the transverse friction coefficient of the pavement.

waste, dumps and emissions to the atmosphere. Along the same lines, work has been done on the development of the concepts that support green public procurement applied to transport infrastructure projects.

Several tests with waste materials have been carried out in the Road Materials Laboratory to verify the presence or absence in them of elements or substances that, either by themselves or by their leachates, could cause pollution in soil, waters or the atmosphere. Tests are also aimed to document its eventual declaration as by-products by the competent authorities, which would mean the end of their status as waste materials and provide clearance for its subsequent application in road construction. Tests have been carried out with copper slags, reclaimed asphalt pavement and NFVU crumb rubber for road construction and sports facilities flooring.

CENTRE FOR HYDROGRAPHIC STUDIES





The main activities carried out in the Centre for Hydrographic Studies (CEH) during 2020 have been structured in accordance with the statutory purposes established for CEDEX in the field of continental waters: activities related to basic nature data and the knowledge of resources and the water environment; standardization and regulations, as well as standards and technical specifications and, finally, advances in research, technological development and innovation.

Specialized technical assistance has been provided to the Ministry for the Ecological Transition and the Demographic Challenge (MITERD) 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 MITERD has been provided through the General Water Directorate (DGA) and the River Basin Authorities. In the case of Foreign Affairs, assistance has been provided to the programs of the Water and Sanitation Cooperation Fund (FCAS) at the request of the Secretary of State for Foreign Affairs and for Latin America and the Caribbean.

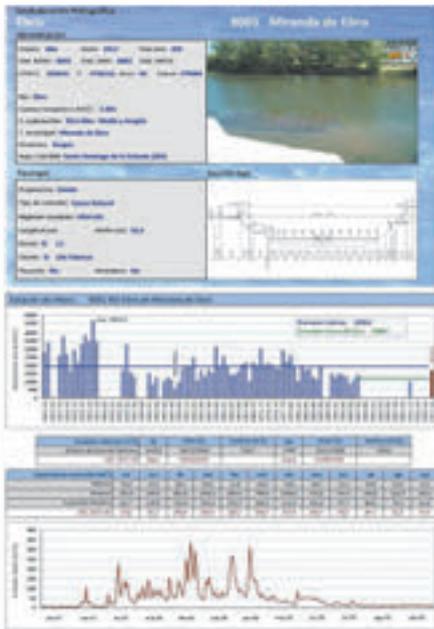
Except for specialized technical assistance, which is carried out through commissions from interested public bodies or through contracts with the private sector, the other activities have been developed trying to meet the needs of the public water administration, for which work has been done on close collaboration with the General Water Directorate.

BASIC NATURE DATA

Updating the HIDRO hydrological database

The new data from the gauging stations, channels, reservoirs and evaporimetric stations corresponding to the hydrological year 2017/18

< The Zufre dam (Huelva).



File of the Ebro River gauging station in Miranda de Ebro, year 2017/18, and cover of the Gauging Yearbook of 2017/18.

have been loaded and the monthly data of: total precipitation, daily maximum precipitation, rainy days, maximum temperature, minimum temperature have been updated, monthly average temperature and monthly average temperatures of daily maximum and minimum temperatures up to October 2020, have been uploaded. The daily rainfall data has also been loaded and validated since it was recorded until October 2020. Data have been provided by the State Meteorological Agency (AEMET) for all its stations.

Preparation and publication of the Gauging Yearbooks corresponding to the hydrological years 2017-18 and 2018-19

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 DGA, providing support to this Directorate in its dissemination and publication work. The activities during the year 2020 for the compilation, unification and validation of the information have allowed progress in the work of preparing the gauging yearbook of the hydrological year 2017/18 as well as its publication. Progress has been made in the work to prepare the gauging yearbook of the 2018/19 hydrological year.

Improvements have been made in the visualization and downloading of yearbook information from the CEH website, <http://ceh-flumen64.cedex.es/anuarioaforos/default.asp>. A new functionality has been implemented that allows the complete download of all the information available in the gauging yearbooks for each river basin authority.

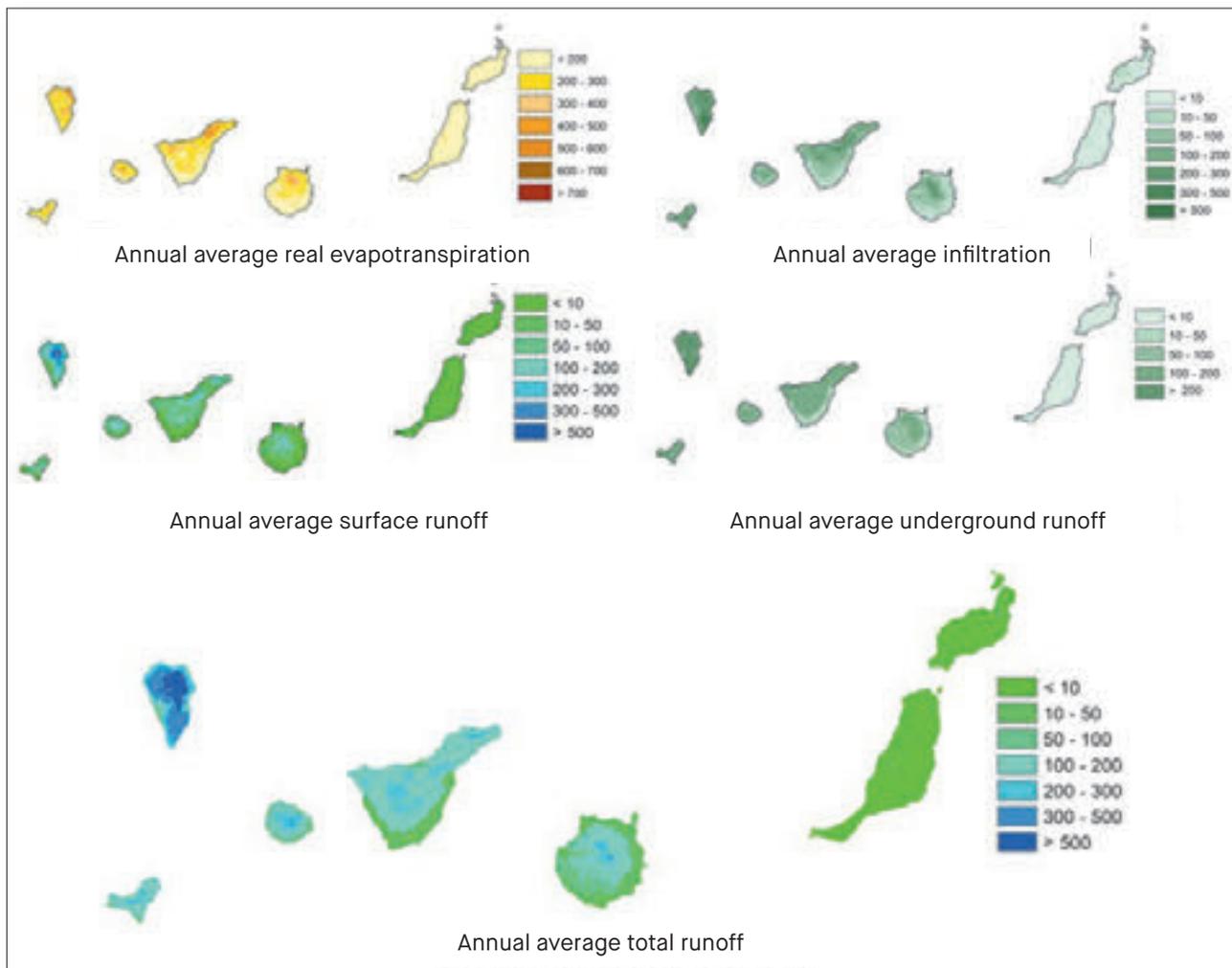
KNOWLEDGE OF RESOURCES AND THE WATER ENVIRONMENT

Updating of the inventory of water resources in natural regime

The results will serve as the basis for the preparation of the River Basin Management Plans for the third planning cycle (2021/2027). The



Since its creation, the Centre collects, analyses and publishes hydrometric data from the Official Network of Gauging Stations.



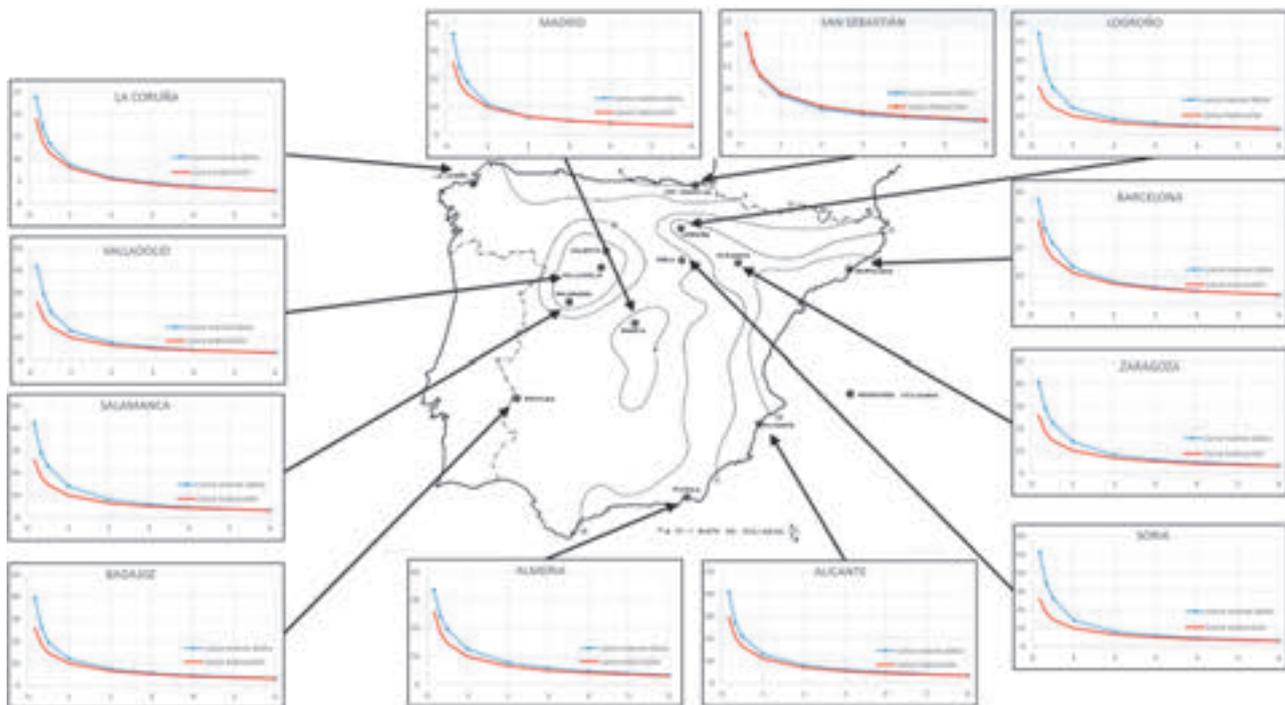
Maps of the resource assessment of the Canary Islands, period 1940/41 - 2017/18.

technical note has been finalized with the description and results of the work carried out in the Peninsula and the Balearic Islands for delivery to the river basin authorities and the requests for particular information from some river basin authorities have been resolved. The Canary Islands resource assessment for the period 1940/41 - 2017/18 was also completed and delivered to the DGA at the end of April, and a document has been prepared to respond to the doubts raised by the General Directorate of Territorial Planning, Ecological Transition and Waters of the Government of the Canary Islands. Finally, work has begun on updating the inventory of water resources in Spain for 2018/19.

Progress has continued in the improvements to the treatment of the underground phase of the SIMPA hydrological model. The operation of the new calculation algorithm has been verified and refined in a local area of the Segura Basin and subsequently, once the data supplied by the Geological and Mining Institute of Spain (IGME) has been received, analysed and adapted, it has begun to simulate the Segura Basin.

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

The national simulation model has been validated with the data from the current river basin management plans of the 2nd cycle and the



consequences of different situations (ecological inputs and flows) on the availability of water resources at the head of the Tagus have been preliminarily evaluated. The different climate change hypotheses have been simulated throughout the national territory according to the report prepared by the CEH on the evaluation of the impacts of climate change on water resources and droughts, updated in 2017 for the OECC.

Contrast of the IDF curves with the new data on precipitation intensities.

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

Review and analysis of the data on rainfall and maximum intensities from the AEMET measurement network, and progress in the review and analysis of the information from the networks of the Autonomous Communities and the SIAR network of the MAPA. Analysis and statistical characterization on a national scale of the series of maximum precipitations in different time intervals from the series of data registered in the AEMET rain gauges and rain gauges. Work has begun to identify homogeneous statistical regions through the application of cluster analysis techniques to the set of AEMET rain gauges, checking the homogeneity by applying different statistical tests.



Work has begun to identify homogeneous statistical regions through the application of cluster analysis techniques to the set of AEMET rain gauges, checking the homogeneity by applying different statistical tests.

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

Work has continued to study the substances included in the Watch List (List II), with the analysis of the compounds contemplated in Implementing Decision (EU) 2018/840, in water samples collected at the end of 2019 in the 37 points selected by the river basin

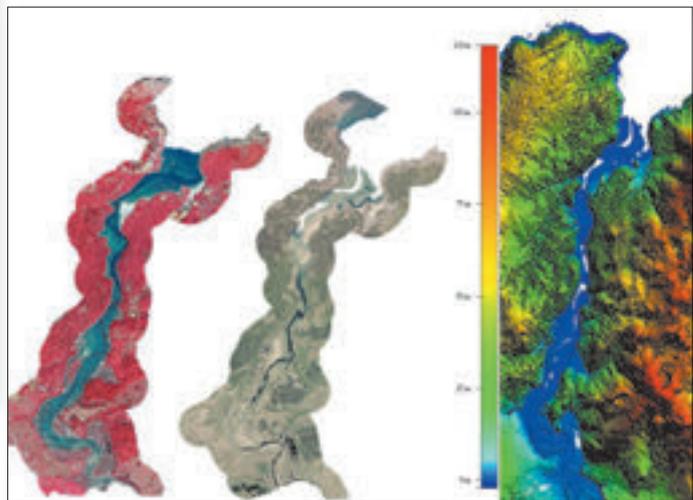
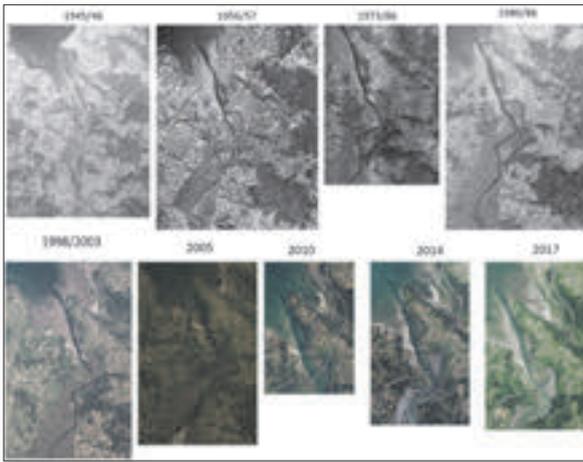
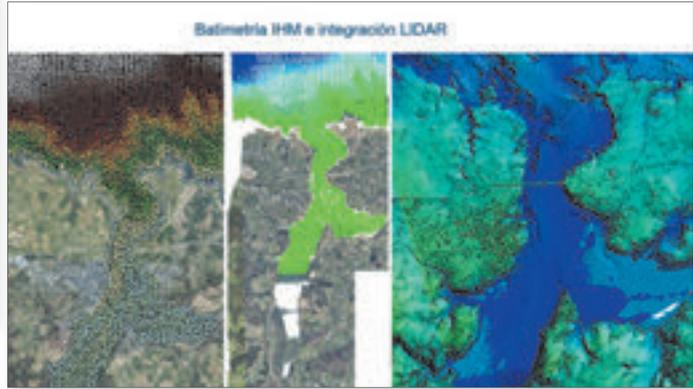


Chromatograms and spectra of some of the compounds tested from the GC-ORBITRAP-HRMS Watch List.

authorities at the outlet of treatment plants and their receiving environment.

Fine-tuning of the methodology for the 19 compounds in the annex to Decision 2020/1161 (watch list III): sulfamethoxazole, a sulfonamide antibiotic, and trimethoprim, a diaminopyrimidine antibiotic, the antidepressant venlafaxine and its metabolite O-desmethylvenlafaxine, a group of threeazole pharmaceuticals (clotrimazole, fluconazole, and miconazole) and sevenazole pesticides (imazalil, ipconazole, metconazole, penconazole, prochloraz, tebuconazole, and tetraconazole) and the fungicides famoxadone and dimoxystrobin. The inclusion of the different pharmaceuticals is consistent with the EU's strategic approach to pharmaceuticals in the environment, and the inclusion of the two antibiotics is also consistent with the European One Health Action Plan to combat antimicrobial resistance, which supports the use of the watch list to "improve understanding of the emergence and spread of antimicrobials in the environment".

From the information collected from the official cartography of the Marine Hydrographic Institute (IHM), the Maritime Terrestrial Public Domain and the BTN25 coastline of the National Geographic Institute (IGN), together with the geological and geomorphological characteristics, data LIDAR, bathymetric data from the IHM, and the analysis of the historical evolution of the final section of the rivers through historical photographs of the IGN, a classification of the rivers mouths has been established, establishing the criteria that have allowed to identify the final point (outlet) of most of the 108 rivers selected in the first phase.



Examples of information analysed to define the types of rivers mouths and their associated criteria.

Early identification and monitoring of invasive alien species of fauna and flora introduced by human activity in surface continental waters

Work has begun to compile bibliographic information on the distribution and evolution of the colonization of exotic and invasive species of continental aquatic fauna and flora in order to expand the study prepared in 2018 for the DGA, in order to include additional species of interest for Spain. Technical advice has been provided to the Working Group of River Basin Authorities on invasive alien species in inland waters.

STANDARDIZATION

The Centre for Hydrographic Studies participates in the Spanish Association for Standardization 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

Support in the implementation of the new European Reuse Regulation

Support to the DGA in the debate on the Regulation on minimum requirements for reused water in Europe (review and answering of



Work has begun to compile bibliographic information on the distribution and evolution of the colonization of exotic and invasive species of continental aquatic fauna and flora



Design of a questionnaire that can be completed by the operators for the rapid and preliminary diagnosis of the water regeneration stations (ERA) that are currently supplying water for agricultural irrigation.

documents, review of the Spanish translation of the Regulation and attendance at technical meetings).

Preparation of two supporting documents for the implementation of the Regulation in Spain. 1.- Identification of the main milestones and tasks that must be taken into account for the implementation of the Regulation. 2.- Proposal of a roadmap, where for each one of the tasks a schedule was proposed to be able to achieve it, complying with the dates provided in the Regulation.

Based on the actions identified by CEDEX, and at the request of the DGA, analyses have been carried out for the normative adaptation and the diagnosis of the reuse facilities has begun to be prepared.

Design of a questionnaire that can be completed by the operators for the rapid and preliminary diagnosis of the water regeneration stations (ERA) that are currently supplying water for agricultural irrigation, in order to have a first assessment of how many facilities are currently in use. Willingness to comply with the new Regulation and have an estimate of the effort required to adapt the facilities.

Dissemination of the content of the Regulation, its implications and the work carried out for its implementation in various forums.

Preparation of a document where the singularities of the Regulation were analysed in relation to RD 1620/2007, which establishes the legal regime for the reuse of treated water in Spain.

Work has begun on a proposal to modify RD 1620/2007 that integrates the new European Regulation.

Development of methodologies and guides for the application of the new European Reuse Regulation

Since 2018, a demonstration project has been developed in the Pinedo-Regadíes WWTP reuse system in Acequia del Oro (Valencia), which aims to evaluate all the implications of the new European regulation, as well as develop methodologies for its implementation and identify the changes to be introduced in our legislation. The project is led by the DGA and has a large working group where all the institutions involved are located. This project has provided fundamental practical knowledge for the negotiation of the European regulation, but it has been necessary to slow down the work in order to have a clear methodology for assessing environmental and health risks and to know the basic determinations of the European guide on the matter.

During 2020, the existing risk assessment systems have been analysed, and new systems have been proposed and tested, both for health and environmental risks. The different systems of validation of facilities that are applied internationally have been studied, in order to evaluate the implications and costs that would have to adopt one system or another.

The European Commission must prepare a guide for risk management, for which it has commissioned the JRC to draw up the base document. CEDEX, at the request of the DGA, is providing support in the follow-up of this initiative.



During 2020, the existing risk assessment systems have been analysed, and new systems have been proposed and tested, both for health and environmental risks.

For the meeting of the Ad-hoc Task-Group on Water Reuse in October 2020, a series of documents drawn up by the Commission were reviewed and comments were provided to establish the Spanish position regarding the content that the European guide should have.

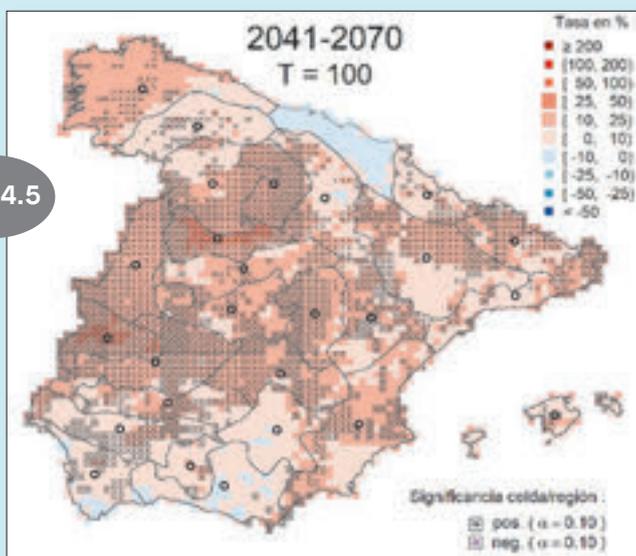
Guide for the cost-benefit analysis of the structural measures of the flood risk management plans.

Completion of the drafting of the guide, the main objective of which is its application in the analysis of the actions provided for in the Flood Risk Management Plans. The guide includes recommendations on different aspects of the cost-benefit analysis (selection of the analysis period, the discount rate, the profitability criteria, the prioritization of investments, etc.). However, most of the guide is dedicated to providing criteria for estimating the damage avoided by flood defence measures on different land uses. Application to the floods that occurred in Jávea in October 2007.

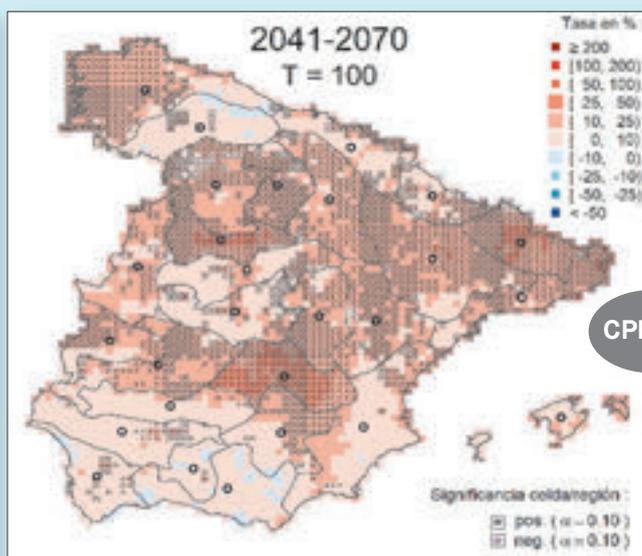
Assessment of the effects of climate change on precipitation and peak flows

Collaboration with the DGA has continued in relation to incorporating the effects of climate change into second cycle flood risk management plans. The study on the impact of climate change on maximum rainfall is almost complete. Analysis of the behaviour of the maximum annual precipitation series from climate models with respect to the observations in the control period, the trends and

CPR 4.5



CPR 8.5



Maps of average rates of change in the 100-year quantile of the return period of the maximum annual daily precipitation for the Peninsula and the Balearic Islands, indicating the cells with statistical significance, for the impact period 2041-2070 and scenarios RCP 4.5 and 8.5.

changes in the statistics of the series during the 21st century have been studied, and the estimation of the average quantile change rates, and those associated with the 10th and 90th percentiles, as well as the evaluation of their statistical significance, for the different impact periods,

Review of the proposal for technical standards for the design of works and facilities for runoff water management

At the request of the DGA, CEDEX is conducting a review of the technical standards on rainwater. The shortcomings and problems of the current regulatory framework have been highlighted, as well as the aspects that would need to be developed in order to be able to draw up the technical standards in an adequate way and for their application to have sufficient legal guarantee.

Review of the technical standards proposal with their drafting team and participation in a pilot exercise for their implementation in eight urban basins throughout Spain, organized by the Spanish Association of Supply and Sanitation (AEAS), in order to detect problems and calibrate their incidence in different climatic and casuistic regions.

Support in the revision of the regulations on sustainable nutrition in agricultural soils

At the request of the DGA, a review of the Draft Royal Decree has been carried out to identify possible repercussions on the water treatment facilities, both with regard to the reuse of wastewater and the disposal of sludge.

Study for the incorporation of climate change in the river basin management plans of the third planning cycle 2021-2027

Delivery to the DGA of a technical note that indicated the percentages of change in runoff and water contribution foreseen for the planning horizon 2039, temporally disaggregated by climatic stations and spatially in the water network and in a series of cartographic units of interest to the river basin authorities. This study was completed to contemplate some cartographic units of the river basin authorities of Andalusia.

RESEARCH, TECHNOLOGICAL DEVELOPMENT AND INNOVATION

The work corresponding to the collaboration with AEMET in the European seasonal prediction research project (MEDSCOPE) has been completed, the objective of which is to study the viability of making predictions of the estimated contributions for the next five months (November to March) in October. This work has consisted of carrying out a set of monthly simulations with the SIMPA hydrological model, for the period 1997-2017, in the watershed of the Belesar reservoir in the Miño-Sil River Basin Authority, based on temperature maps and precipitation supplied by AEMET from three different sources: from the observational grid prepared by AEMET, of regionalization by analogues of the ERA-Interim reanalysis of the ECMWF (European Centre for



Review of the technical standards proposal with their drafting team and participation in a pilot exercise for their implementation in eight urban basins throughout Spain.



The Ebro River.

Medium-Range Weather Forecasts) and of seasonal regionalization predictions of 25 members of the ECMWF-ERA5 seasonal model. Contributions to the descriptive document of the experiments carried out and their evaluation, "Seasonal forecasts of winter inflow for Belesar Water Reservoir", prepared by AEMET and distributed among the participants of the MEDSCOPE project.

Participation as an associated entity in the research project CO-MICC (Co-development of methods to utilize uncertain multi-model based information on freshwater-related hazards of climate change; <http://www.co-micc.eu/>) whose objective is to jointly use global water models to support adaptation to climate change at various scales. Proposals have been analysed and developed to improve a web portal with data and results from multi-model ensembles hosted at the International Centre for Water Resources and Global Change (ICWRGC) of UNESCO. It is a global study, but it focuses on the Ebro basin and three other Basins in Morocco, Algeria and Tunisia.

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), whose objectives are to investigate and establish common criteria in the monitoring of these water bodies, improving the integration of the environmental objectives of the Water Framework Directive and the Habitats Directive, and raising awareness about cooperation in shared river basins. The project is promoted by the DGA and by the Portuguese Environmental Agency. Carrying out sampling campaigns in border and transboundary water masses (reservoirs and rivers), obtaining data from the biological

indicator ichthyological fauna in rivers, for the evaluation of the ecological status.

At the request of the DGA, the CEH is part of the central decision-making team of the project "SARS-CoV-2 Monitoring employing Sewers" promoted by the European Commission through the Joint Research Centre (JRC). Participation in numerous meetings, conferences and workshops (environmental monitoring methodology, commitment to health authorities, sampling methods, analysis of SARS-CoV-2 in wastewater samples). This project has been valued by the European Commission in its communication of 11/11/2002 called "Building a European Health Union: Reinforcing the EU's resilience for cross-border health threats " as a way to track infections and as a possible early warning mechanism. In addition, it has also laid the foundations for the development by the European Commission of Recommendations for a systematic surveillance of SARS-CoV-2 and its variants in wastewater from the European Union.

Updating and improvement of the Iber two-dimensional mathematical model for calculating flood areas in rivers. New version of the code in FORTRAN CUDA that allows it to be executed on graphics cards (GPU), which optimizes the previous FORTRAN code, improving its calculation performance and reducing computing times (although the initial option of computing in CPU is also maintained).

Stoppage of the suspended sediment transport module and the most commonly used turbulence models. The use of this tool is enabled for the study of erosion and sedimentation processes in channels associated with suspended transport.

Improvements in the SPHERIMENTAL model, a 3D numerical development of CEDEX for hydraulic studies carried out in the Hydraulics Laboratory. Possibility of introducing pumps to study the approach flow, improvement of the input contour conditions to allow feeding variable flows in fast or slow regime, enabling the code to guarantee its representativeness in the study of flows in load in pipelines and inclusion of some utilities for oleo studies (such as the initial condition of automatic fill of the model to a dimension, or a condition of moving oleo palette boundary whose movement is prefixed by a series).

In relation with Information Technology, several works have been carried out:

- Rewiring project and high speed network. Installation of a new high-speed OM4 fibre optic network and configuration of the equipment to create a new 10 Gbps communications backbone that joins all the CEH communications equipment.
- Implementation of a collaborative work tool during the initial state of alarm and confinement period (March 2020) to improve collaboration mechanisms within CEH units.



Improvements in the SPHERIMENTAL model, a 3D numerical development of CEDEX for hydraulic studies carried out in the Hydraulics Laboratory.

- Implementation of the phpBB tool for the Water Technologies area of the CEH. Virtual services infrastructure to offer a collaborative tool in forum format for the study of COVID-19 in wastewater.
- 3D scanning with LiDAR laser of the testing hall of the Hydraulic Laboratory and the most important rooms of the CEH (Auditorium, Meeting Room, laboratories with outstanding equipment and main stairs).

On June 3, the researcher Beatriz Gómez Gómez defended in online format her doctoral thesis "Synthesis and characterization of metallic and metalloid nanoparticles. Evaluation of its interaction with bacterial populations for applications in the food sector", with an International Mention in the Department of Analytical Chemistry of the Faculty of Chemical Sciences of the Complutense University of Madrid.

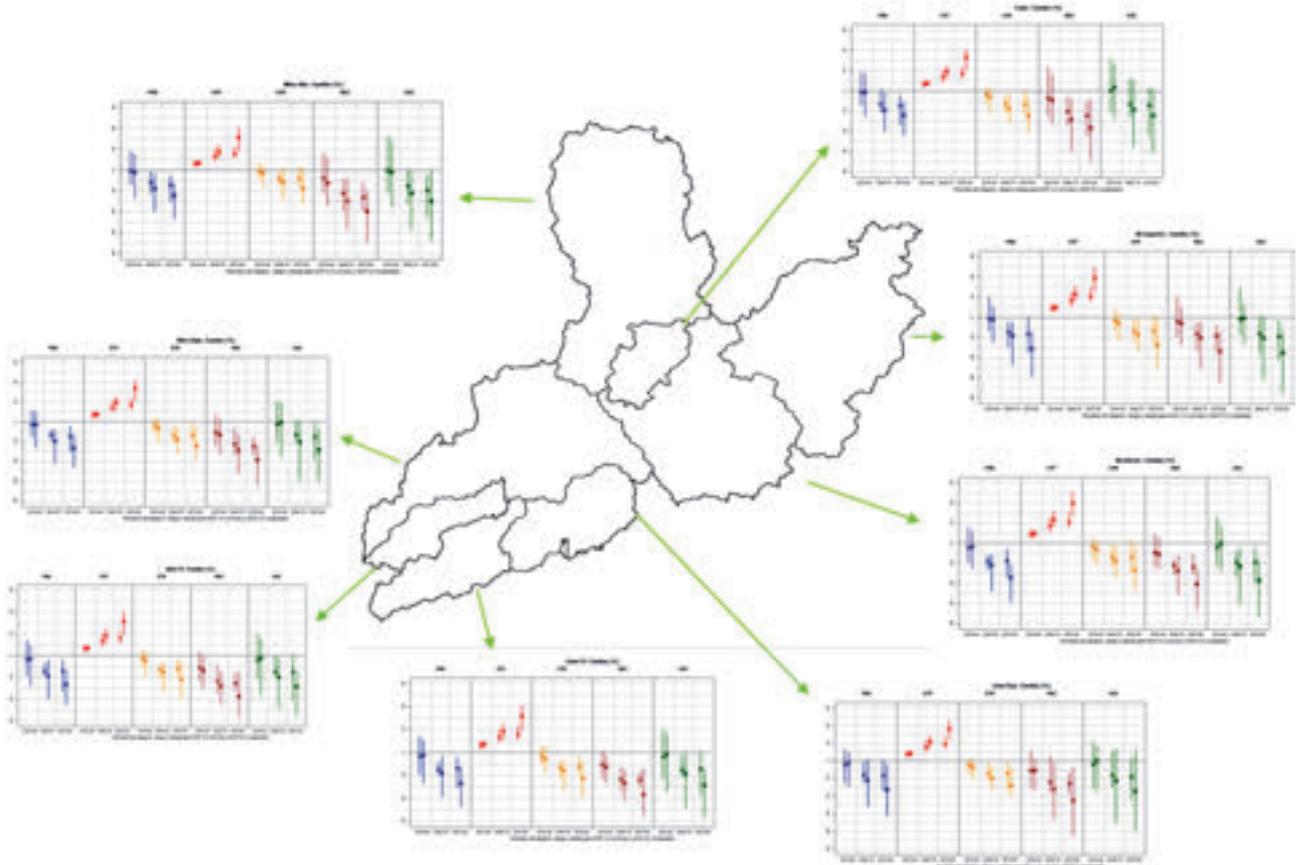
SPECIALIZED TECHNICAL ASSISTANCE

Specialized technical assistance to the General Water Directorate in solving specific problems or supervising works commissioned to third parties, through orders from the river basin authorities or through participation in work groups.

- Assessment of the impact of climate change on the water resources of the Spanish and Portuguese parts of the hydrographic basins of the Miño and Limia Rivers (Miño-Sil River Basin Authority).
- Support in the monitoring of the Study of solutions and preliminary projects of the actions in sanitation and purification of the agglomerations of La China, Butarque and Sur de Madrid.
- Supervision of the migration of the CAUMAX application from gvSIG to QGIS.
- Monitoring the update of the runoff threshold parameter map.
- Study on the determination of the ecological flow regime established in the river basin management plans of the second planning cycle 2015-2021, in collaboration with CETA.
- Advice on the implementation of the National Emissions Ceilings Directive (EU 2016/2284).
- Surveillance of the possible impact of the Bellús reservoir on the groundwater in its surroundings (Júcar River Basin Authority), in collaboration with CETA.
- Support in the project Microbiological surveillance in wastewater and bathing water as an epidemiological indicator for an early warning system for the detection of SARS-CoV-2 in Spain (VATar COVID-19).
- Assistance in technical issues related to the Conference of Ibero-American Water Directors (CODIA).
- Commission for technical assistance, research and technological development in continental hydraulics.
- Study in physical hydraulic models with erodible bed of the reincorporations to the channel of the outlet structures of the Zufre dam (Guadalquivir River Basin Authority).



Specialized technical assistance to the General Water Directorate in solving specific problems or supervising works commissioned to third parties, through orders from the river basin authorities or through participation in work groups.

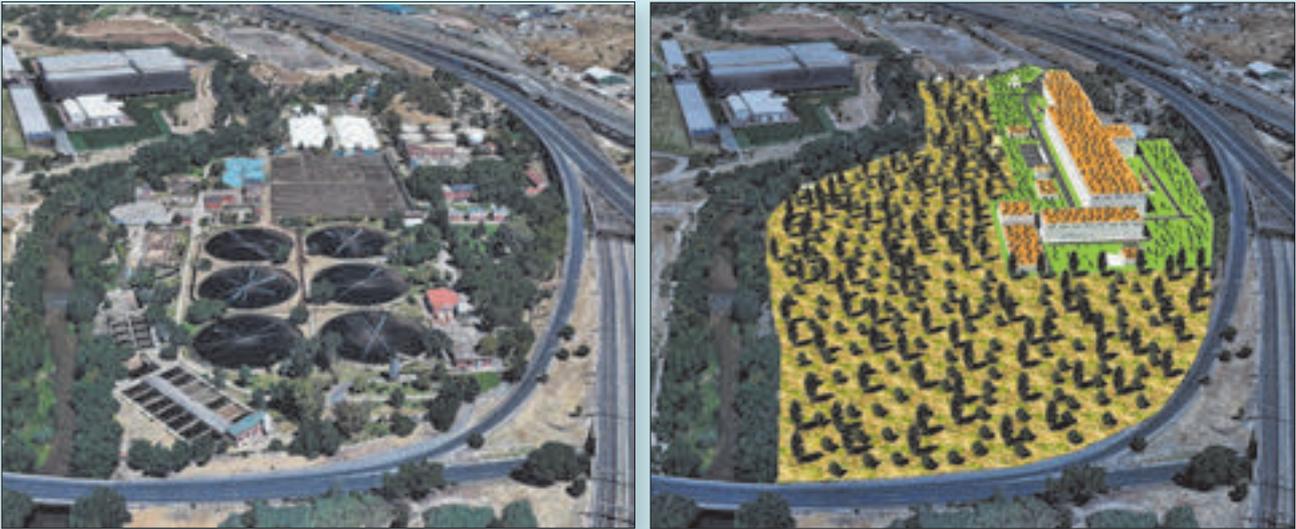


Change (%) in the main hydrological variables for the exploitation systems of the Miño-Limia International River District. Range and mean of results for RCP 4.5 (circles) and RCP 8.5 (squares).

- Study of the influence of the exploitation of the Marmolejo dam (Jaén) on the sedimentation of the reservoir and the flooding of Andújar.
- Plan for the protection of the Ebro Delta: studies to update the characterization of the sediments in the Mequinenza and Ribarroja reservoirs and study of the sedimentary transit in the lower reaches of the Ebro River.
- Analysis of the hydraulic design of the northern interceptor of the city of Murcia.

In the case of the Ministry of Foreign Affairs, European Union and Cooperation, specialized technical assistance has been provided to the programs of the Water and Sanitation Cooperation Fund (FCAS), at the request of the Secretary of State for Foreign Affairs and for Ibero-America and the Caribbean. The work has consisted mainly in the orientation, supervision and review of the projects developed by the Fund, as well as in the generation of knowledge products.

- Collaboration in the development of a guide on the implementation of wastewater treatment systems in Bolivia.
- Diagnosis of treatment plants in Bolivia.
- Optimization of the hydrodynamic design of the rehabilitation of the Casablanca pumping station (La Habana, Cuba).
- Support in the revision of the Sanitation Plan of La Habana.
- Review of the regulations on discharges in Guatemala.
- Support in sanitation actions in Asunción (Paraguay).



La China sewage treatment plant. Left: current plant. Right: Three-dimensional view of the proposed new plant.

- Support in the development of a training program in Paraguay.
- Support in the review and development of sector regulations in El Salvador.

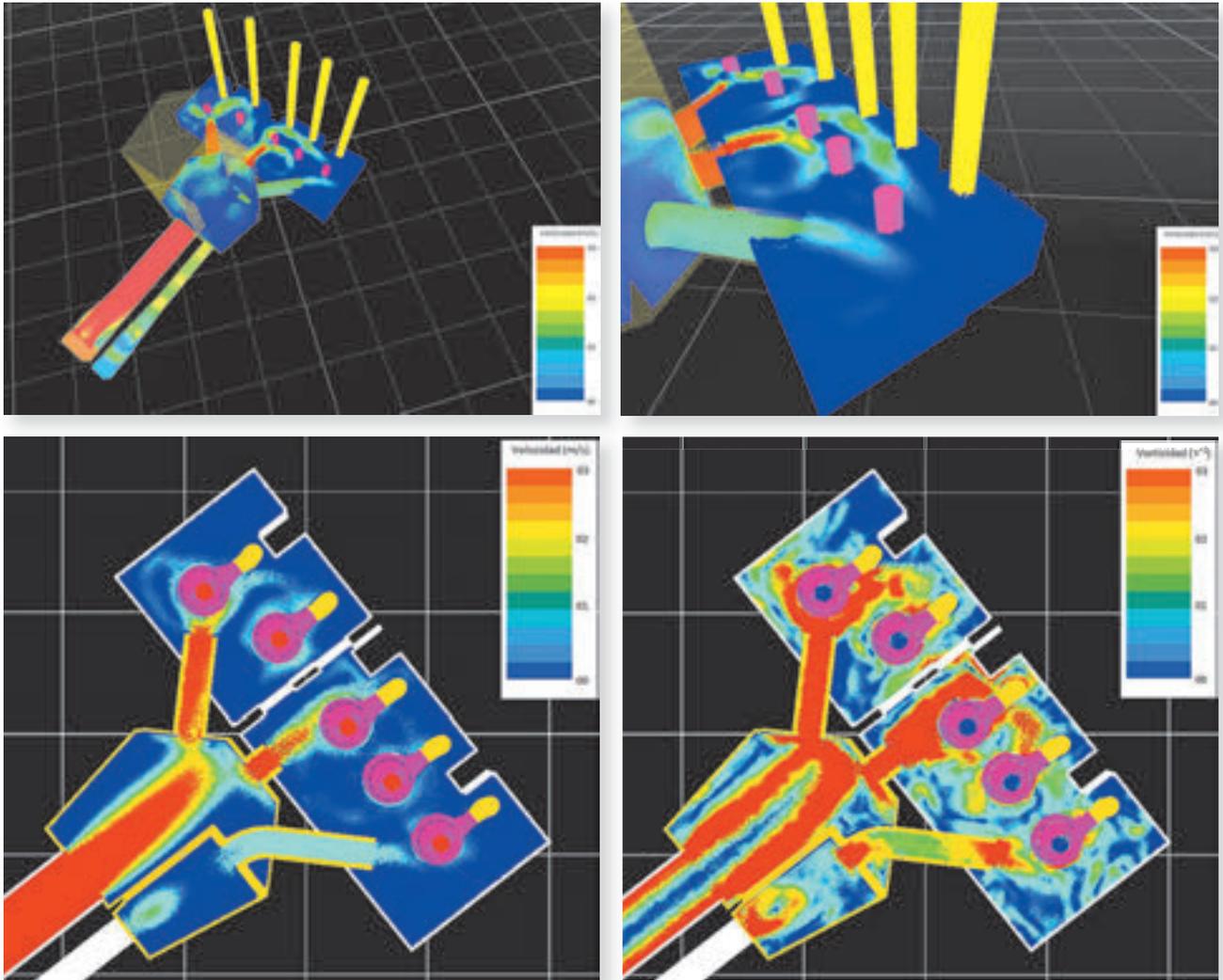
In addition to the actions in each of these countries, work has also been done on different initiatives of a regional or cross-cutting nature.

- Preparation of guides on water and sanitation.
- Preparation of recommendations for sectoral planning in wastewater treatment.
- Support in the FCAS regional strategy on sectoral regulations.
- Support in the design of the FCAS facilities database.

Completion of the contract with the Development Bank of Latin America (CAF) to provide technical assistance in the preparation of the "National Wastewater Treatment Plan of Argentina". The Centre



Design proposal for the stilling basin for the bottom outlets of the Zufre dam.



Velocity and vorticity simulations with the SPHERIMENTAL model at the Casablanca pumping station (La Habana, Cuba).

collaborated with the National Directorate of Drinking Water and Sanitation of Argentina in the definition of objectives, in the prioritization of actions and in the estimation of costs of actions. Additionally, a proposal of normative content for the reuse of wastewater was prepared. During this period, trips to Argentina were not possible due to the pandemic.

Technical assistance to the private sector:

- Hydraulic study of the structures of the Canal del Enlace Directo, Huelva (UTE Sando, SA - Inersa, SA).

RAILWAY INTEROPERABILITY LABORATORY





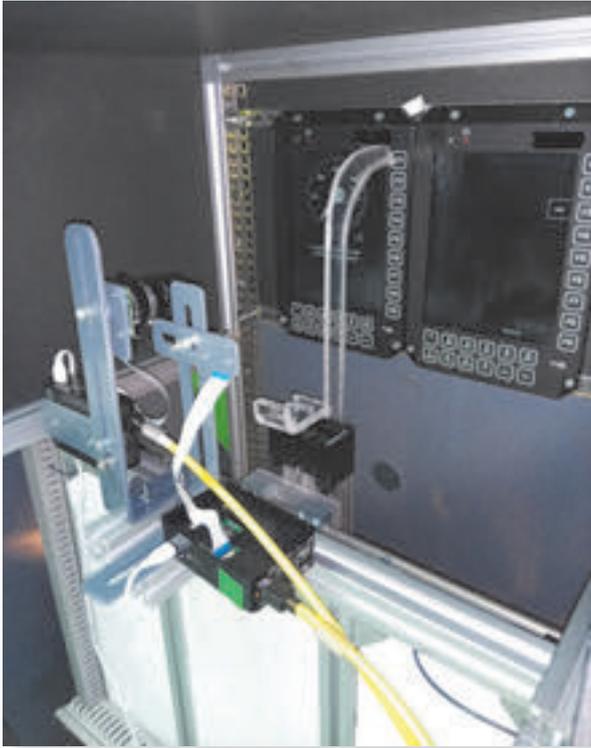
In 2020 the Laboratorio de Interoperabilidad Ferroviaria (LIF) has continued its main activities, which will be summarized in the following paragraphs. In spite of the enormous impact caused by the Covid-19 on the whole economic activity and, also, on the railways field, the LIF has been able to maintain its activity, adapting to the new working conditions.

First of all, it's worth highlighting how at the beginning of the lockdown, in March 2020, the LIF staff were immediately adapted to teleworking, and in three days all the staff were working at home once the connection was arranged by CEDEX IT team. During this time, the LIF activity wasn't interrupted at all, and although testing in the lab was postponed, a high level of activity was accomplished through teleworking.

The most relevant project started during the lockdown was the "Project of ERTMS On-Board Unit Test Automation". The LIF software group was organized to develop both the software and hardware, which will allow the automation of Subset-076 tests, with the aim of developing the SW tools needed to deploy the system at lab once the staff return to the workplace. Therefore, during this period the software development was organized and the activity was started. Once the confinement was over, the robot assembly was completed at the lab, and all the software units were joined together.

In this way, the following goals have been achieved: 1) Subset-076 Test Sequence automatic execution by means of the robot driving the DMI (Driver Machine Interface); 2) DMI recording and automatic events generation by means of the image recognition system; 3) Automatic downloading and storing in the different server folders of all the events related to JRU (Juridical Record Unit), TIU (Train Interface Unit) and DMI; and 4), Test Sequence pre-analysis by

< Night view of a train station.



DMI Drive Robot.

means of the developed software of automatic analysis of events and Test Sequence steps.

This development, which constitutes a great advance for the Eurocab Laboratory, is already being applied to the Hitachi OBU BL3-R2 test campaign, allowing an important time reduction for both execution and analysis of the test sequences. As an example, by using these tools, a "Play List" of 100 test

sequences can be automatically executed in 8 hours, while the previous manual execution of these 100 sequences by a LIF expert took between one and two weeks. This substantial time reduction, together with the improvement in Test Sequence analysis, allows to run a Subset-076 complete test campaign (more than 700 test sequences) in half the previous time. It's a good example of how a project partially developed during the lockdown has been extremely successful.

The second project that has entailed important activity in 2020 for the LIF has been the European Project GATE4RAIL. This project has consisted of a collaboration, among various European partners and laboratories, for the design and development of a geo-distributed testing platform for the simulation of ERTMS lines equipped with the so called "virtual balises". The concept of virtual balise involves a balise that doesn't exist physically on the track, being its telegram stored in a data base and sent to the ERTMS On-Board Unit when the train reaches a predefined position. The train position is accurately determined by a GNSS (Global Navigation Satellite System) receiver on board. Thus, the use of GNSS allows to eliminate real balises on track, and to design an ETCS line without any real balise installed on track.

A Belgium lab (M3 Systems) generated the GNSS signals corresponding to the train location (time and position), and sent these signals to an Italian lab (Radiolabs), which generated and sent to the LIF the virtual balises triggering. The LIF, for its part, sent these virtual balises telegrams to an industrial ETCS On Board Unit (OBU), equipping a virtual train circulating on a Spanish line.

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The most relevant project started during the lockdown period was the "Project of ERTMS On-board Unit Test Automation", which has been a complete success.

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The concept of 'virtual balise' consists of a balise that doesn't exist physically on the track, but its telegram is stored in a data base and sent to the ETCS on-board equipment when the train reaches a predefined position.



Line Almorchón-Alhondiguilla on which the GATE4RAIL project was executed.

The LIF staff designed an ERTMS engineering of its own with virtual balises on the line Almorchón-Alhondiguilla, between the provinces of Badajoz and Córdoba. On this line, and in ETCS Full Supervision mode, it made the virtual train equipped with the industrial OBU run. Likewise, it was simulated at the LIF the circulation of this train on the Italian line in Sardinia, also equipped with virtual balises.

On returning from confinement, the LIF staff carried on testing at lab the ETCS lines expected to be tested in 2020. It was continued the testing of Barcelona commuter lines (Badalona-Mataró) with an Alstom OBU BL3. This test environment will continue at the LIF up to the final execution of the tests in June-July 2021.

Further, it was completed the final tests of two ETCS lines to be placed in service in the near future. The first one is the Atlantic Corridor connecting the cities of Vigo, Pontevedra, Santiago de Compostela and La Coruña. This is a level 1 line equipped by three different companies, Alstom, Caf and Siemens (UTE SACAT), and the tests were carried out with three different OBUs from Alstom, Caf and Bombardier, thereby resulting in nine interoperability combinations. The reports of these nine test campaigns were forwarded to the client in July 2020. This project already equips with ERTMS the Santiago de Compostela station and its connection with the Orense-Santiago HSL.

Additionally, in the last quarter of 2020, it was completed the tests of the HSL Valladolid-Burgos-León and, more specifically, the branch between Venta de Baños and Burgos, a L2 line equipped by



Bombardier. In this case, tests were executed with Alstom and Caf OBUs, and the reports were forwarded to the client (UTE ABI Corredor Norte) in December 2020.

HSL Valladolid-León-Burgos tests at CEDEX's LIF.

Finally, it's important to highlight that due to Covid-19, it was cancelled a ERTMS course expected to be held in September 2020 at LIF premises by the LIF staff. However, the LIF staff began preparing an online course, signing in December 2020 a contract with the Finish company Proxion so as to conduct the course remotely in the first months of 2021.

Other activities performed in 2020 are summarized as follows

Preparation and delivery of the European project RAILGAP with a consortium between companies from Spain, Italy, France and Germany. Later on, this project has been selected by the GSA (European Global Navigation Satellite Systems Agency) to be financed.

Technical assessment to the Spanish company ENYSE for the development of a RBC (Radio Block Center) for ERTMS level 2.

Preparation and remission of an offer to deploy a lab similar to the LIF for the English Inframanager Network.

Starting of the activities related to the European Working Group defining new release of Subset-076 (Test Specifications of ERTMS) to be published in the 2022 TSI (Technical Specifications of Interoperability). This work is financed by the EC through Shift 2 Rail Joint Undertaking.

CAF BTM (Balise Transmission Module) test at the Eurobalise Lab.

Creation of the European Association EAL (ERTMS Accredited Labs), together with other four European labs: DLR in Germany, Multitel in Belgium, RINA in Italy and LEF in France.

Continuation of the preparatory works with Adif, AESF (Estate Agency for Railways Safety), Renfe and Ineco for the creation at LIF of the "National ERTMS Lab".

Renewal in April 2020 of the LIF Accreditation Certificate by ENAC (Spanish Accreditation Agency). It was the first time ENAC performed remotely this accreditation audit.

Starting relationship with Trenitalia to support it in the process of ERTMS validation of the trains that will operate in Spanish HSL.

Definition of the new location for the future Hyperloop testing premises on an old track (now a green line) between the villages of Argamasilla de Alba and Alcázar de San Juan, in Castilla-La Mancha. Drafting of an agreement with Adif for renting this green track land out to CEDEX.

THE CENTER FOR PORT AND COASTAL STUDIES





The Center for Port and Coastal Studies (CEPYC) performs functions of CEDEX in maritime waters and its natural and artificial infrastructures through actions related to ports, maritime transport, coasts and marine environment. The combination of a multidisciplinary human team and an advanced set of tools provides the capabilities to apply, with high availability, science and technology to solving problems at the service of the social, economic and environmental sector related to these areas and, in the first place, to those under the responsibility of the executive units in MITMA (Ports of the State and State Ports of General Interest, Merchant Marine Directorate, CIAIM) and MITERD (Directorate General of the Coast and the Sea, OECC and ACUAMED).

The year 2020 has been particularly marked in the CEPYC by two significant events whose positive impact represents a substantial improvement of the Centre's capabilities for the coming years. The human team has been strengthened with the incorporation of 8 researchers contracted to participate together with the staff of the Center in different Research, Development and Innovation projects; its integration into the consolidated work teams will allow to move faster in various important directions and represents a change of trend in the evolution of the Center's staff. And the facilities have advanced with the processes of renovating the CEDEX multidirectional swell tank and the ship maneuver simulation unit to be completed in 2021.

R&D&I projects that benefit from these additional human resources include, in the field of experimentation, those corresponding to new developments and applications in physical models testing for maritime engineering and the implementation, development and application of new techniques in the experimentation of maritime structures. In relation to studies on the coast and the sea, research on the implementation of climate change adaptation measures in

< Drone aerial view of a dock.

coastal areas and the marine environment and research in innovative techniques of remote monitoring in the coastal environment for the planning and follow up of developments on those areas.

With regard to numerical experimentation in the marine environment, complementary to that carried out through physical scale models, the projects of implementation, development and application of new numerical techniques in studies of response of maritime structures and the implementation, development and application of hydrodynamic numerical models applied to marine environmental hydraulics. In this sense, recent studies are supported by complementary applications of numerical and physical modelling, in order to enhance the use of both techniques, which contributes to improve the quality and reliability of the studies carried out.

Along with physical and numerical modeling, data is the third base element of the center's work. In this sense, the project of digitization, acquisition, treatment, analysis of big data and development of applications in maritime engineering undertaken by the systems engineering unit of the Center stands out. Work is underway on the implementation of three projects in the context of MITMA's 2020 – 2021 Digitalization Plan, including the development of the AIS Historical Database and its analytical applications in Maritime & Port Traffic, Fisheries and Environmental Effects, Navigation-Related Risks and Special Activities at Sea, undertaken thanks to the support of SASEMAR.

The CEDEX multidirectional waves tank was put into service in 1,992, one of the first in the world with the ability to conduct three-dimensional port and coastal studies with the highest degree of realistic reproduction of nature's waves. With a very high level of

New multidirectional waves tank.





Renewal of the ship maneuvering simulator.

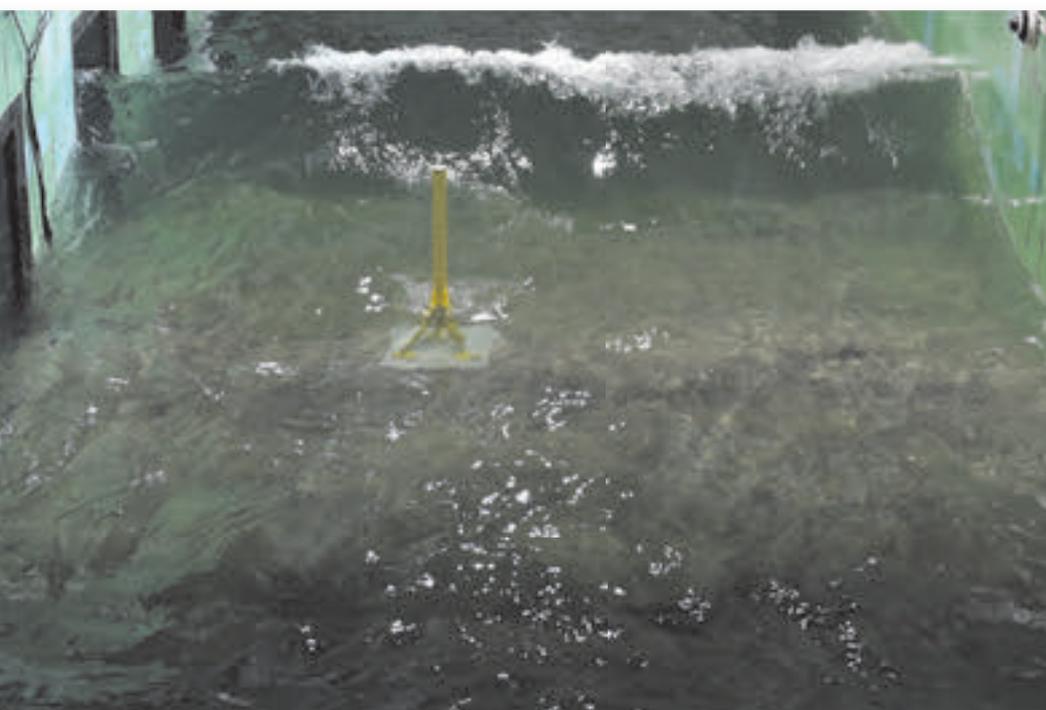
occupancy since then, its use has included participation in several European research projects within the EU framework programmes and in numerous applied research projects for the design of large port structures in Spanish ports, in the study of coastal engineering problems and, in the last decade, in studies on renewable marine energy. The renovation of this unique facility in 2020 has consisted of providing it with a new wave generation system, a control system with active absorption of reflections and a deepening for allowing a greater water depth in the experiments. This improves the quality and range of test conditions of the installation.

Work has been done also along 2,020 on the renovation of the simulation equipment of the CEDEX ship maneuvering unit, originally established in the early 1,990s with a first bridge simulator to study, including the human factor, navigation in restricted waters. In the early 2,000s the unit was updated, with a realistic full mission main bridge, a secondary bridge and suitable dependencies for instructor posts, tugs control and simulation management. The usefulness of these facilities both in the studies related to the design of port development and the safety of port navigation has made them extraordinarily demanded at all times. The very nature of the installation requires frequent updates, and by 2020 a major renovation has been addressed affecting the instrumental physical equipment of bridges, auxiliary equipment, computer systems and logical components. This update is already partially in service at the end of the year and will be completed in 2021, giving the unit expanded capabilities.

Throughout 2020 the activity of the Centre has continued to develop with main attention to the needs of the aforementioned



View of a physical 3D model of the expansion of Escombreras Dock.



Large scale physical model of the buoy of Pasajes Harbour.

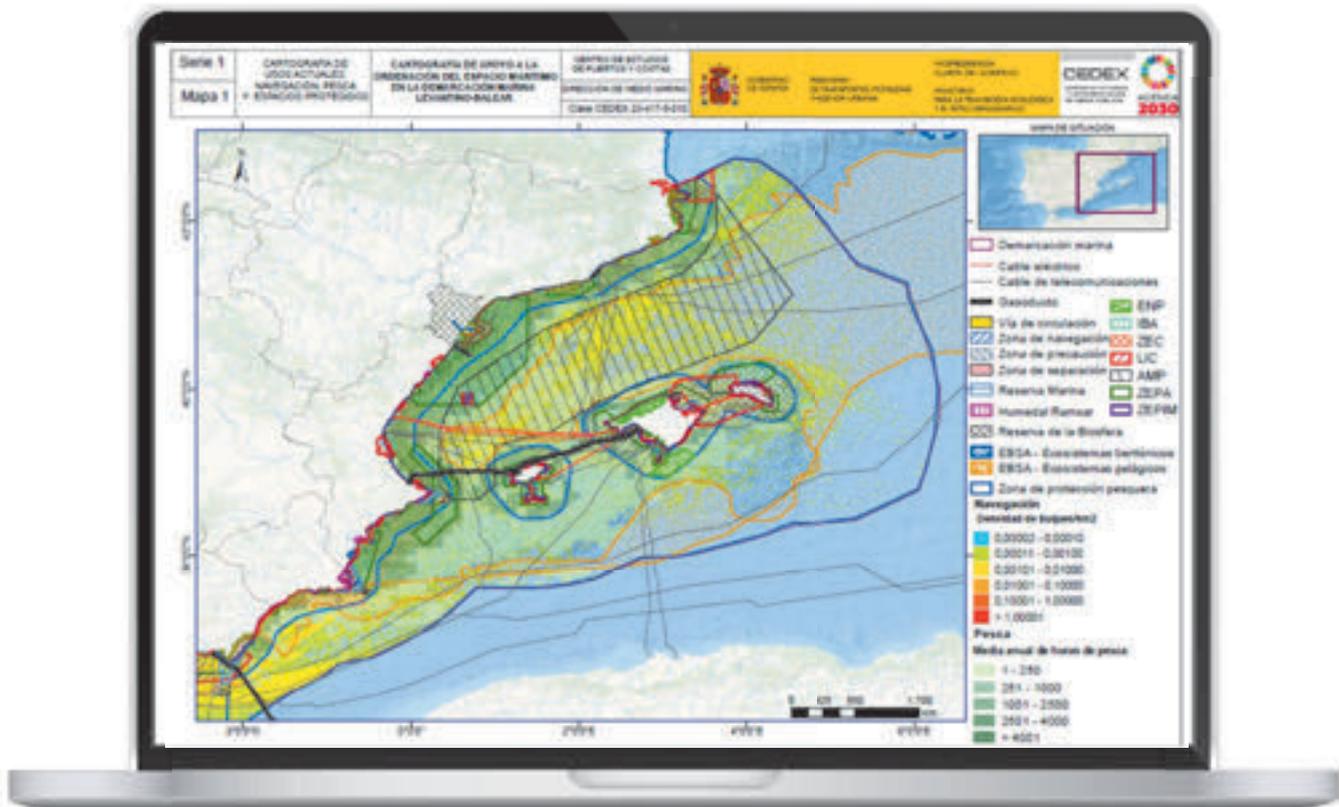
entities, with the results presented in 45 technical reports issued throughout the year.

For Ports of the State, work has been carried out in the framework of the general 2018 – 2020 commission and, starting from the middle of the year, on the new commission 2020 – 2022, both collecting activities to be carried out by CEPYC and also by CETA, LCEYM and LG. The work delivered deals with the characterization and management of dredged materials, the elaboration of the Climate Atlas of design waves on the Mediterranean and Balearic coasts and the studies of overtopping produced by waves on dikes of different

cross sections with comparison of field measurements, empirical formulations, computational fluid mechanics techniques and artificial intelligence predictive tools. Other works under implementation at the end of the year are those corresponding to the estimation of greenhouse gas emissions by ships in the port environment and the identification of geochemical anomalies on the coast in relation to the management of dredged materials; as well as experimentation in a 3D model of the port of Las Palmas of the applicability of different quantitative criteria for allowable movements for ship loading and unloading operations.

Other work for the state-owned port system is carried out through specific agreements supported by State Ports and the requesting Port Authority (AP) in each case; in 2020 work has been made for the Valencia Port, with four specific ship maneuvering simulation studies and a physical 3D model study of wave disturbance and related operational state of new container terminal of the northern basin of the Port. For the Cartagena AP, an important 3D physical model test and agitation studies in numerical model and maneuvering have been carried out for the expansion of the Escombreras basin. For the Ports of the Balearic Islands, the maneuver studies have been completed in the new configuration of the SW basin of the Port of Palma de Mallorca and a study of ship traffic management and related programming of operations in that same basin. Finally for the Bilbao AP a study of hydrodynamic phenomena has been carried out in the berth No. 3 of Petronor including data collection and comparison with numerical results. Under this same scheme, another activity in 2020 that continues development in 2021 is, for Aviles AP, a study of alternatives for sustainable management of dredging

Map of the Mapping Annex prepared for the Draft Planning Plans.



material and elaboration of an Action Plan. Finally, with funding from the Huelva AP, a pilot study is being developed to implement the subacutic confinement technique of port sediments.

For the Directorate-General of the Coast and the Sea (DGCM) special efforts have been carried out throughout 2020, with 20 reports collecting results from work subject to the 2017 – 2020 Commissioning to CEDEX for developing applied research, technological development and innovation in matters within its competence; LCEYM and LG also participate in this agreement in their fields of expertise. In addition to studies on the evaluation of marine waste sources and the London, Barcelona and OSPAR conventions, with participation in their working groups, an important dedication is directed to the processes of implementation of the European Water Directives, Marine Strategies and Marine Space Planning. In relation to the Strategies, it is particularly noteworthy the monitoring of human activities that have an impact on the marine environment and the monitoring program of microplastics on beaches while maritime space management (OEM) is at a time of particular intensity prior to the publication of draft plans, compiling and analyzing the sectors, uses and activities at sea and in the different Spanish marine demarcations, as well as the analysis of land/sea interactions. CEDEX has supported DGCM, the coordinating body for its implementation, participating in working meetings with the departments of the General Administration of the State and Territorial Administrations with responsibilities in the marine environment as well as with other public and private groups of stakeholders.

A common supporting tool for the development of the Marine Strategies and Spatial Planning has been the production of the Marine Environment Information System, INFOMAR, which integrates and makes available to society at large more than 600 data sets on various aspects of the sea, its biota, its physical geography, transport, the environment and many other aspects including activities that take place in Spanish seawater.

Two specific chapters of the Encomienda are devoted to the studies for the planning and execution of actions of the Directorate-General, with the Plan for the Protection of the Coastal Edge of the Lesser Sea and the Plan for the Protection of the Ebro Delta (the latter issued in 2021), two unique coastal spaces of our coasts, and the study of the effects of Storm Gloria on the peninsular Mediterranean coast included several campaigns for the assessment of its effects from Cabo de Palos (Murcia) to the mouth of the Ter River in L'Estartit (Girona). Also worth to highlight are the experimental, applied research studies on sediment transport in groin fields (conducted in the multidirectional wave tank), on runup and beach profile evolution during storms conducted into the large scale wind and waves flume. An applied study has also been performed for studying methods of reduction of overtopping on the beach promenade of the Sardinero Beach, Santander.

With regard to the morphodynamic monitoring of particularly sensitive stretches of coastline, field work has been carried out on

Buildings on the beach of Tabernes (Valencia), after Storm Gloria.



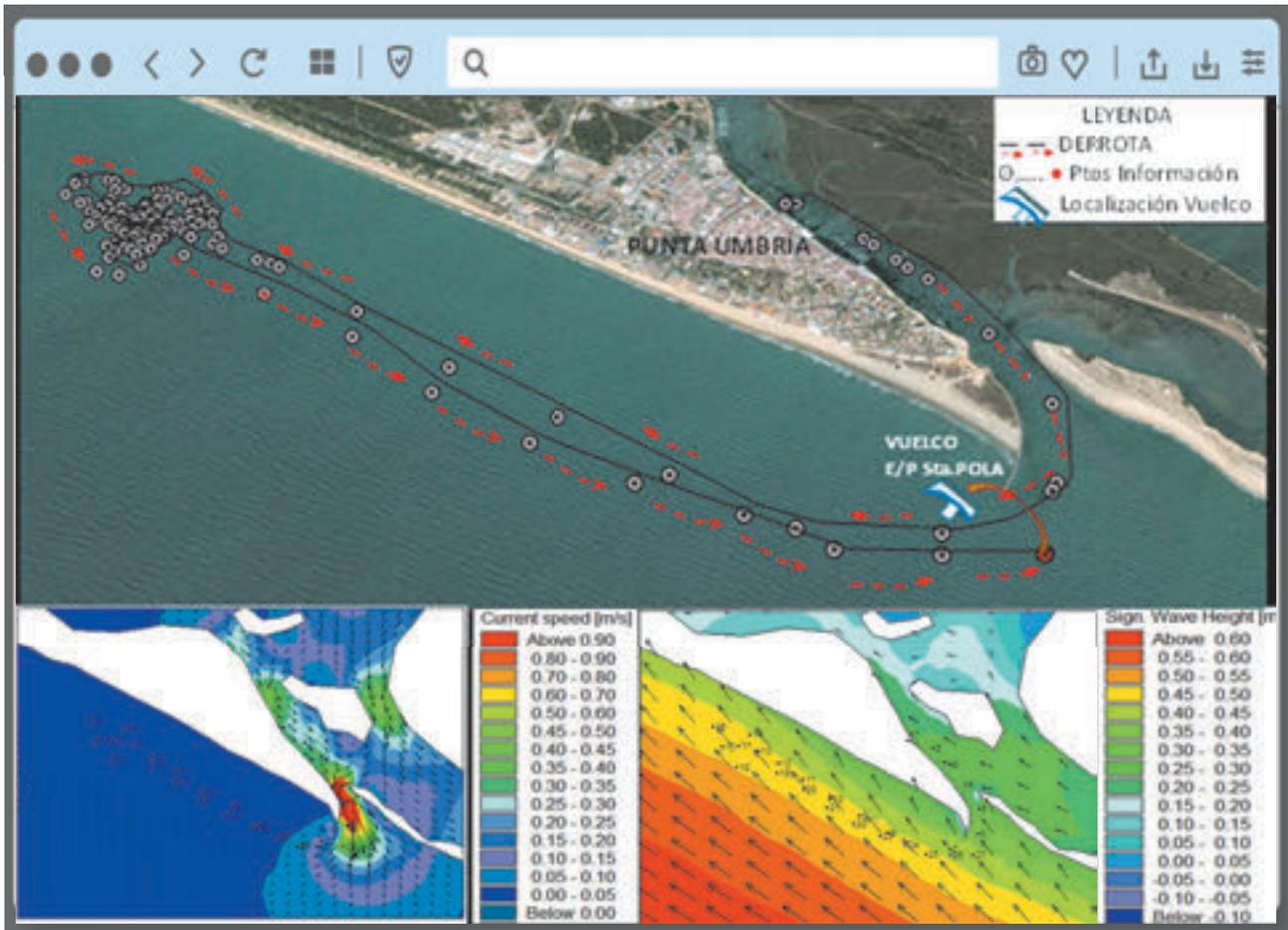
Over the seafront of El Sardinero (Santander) in 3D physical model.



the beaches of Puntal de Laredo (Santander) and Zurriola (San Sebastián).

CEDEX has been working since 1993 for the Directorate General of the Merchant Navy, having carried out more than 200 technical studies. In 2020 progress has been made in the processing of establishing a new biannual work commissioning that will resume these activities including new work topics. Also regarding Maritime Transport, for the Committee of Investigation of Accidents and Maritime Incidents (CIAIM) three studies of oceanic and atmospheric meteorology conditions during the occurrence of accidents of the ships Marsua J, Santa Pola and Silvosa have been carried out in order to determine the possible influence of these conditions on accidents, fulfilling the commissioning made by CIAIM to CEDEX corresponding to the year 2020.

The development of the studies commissioned by ACUAMED for the period 2017 – 2021 has continued, now focusing on the discharges of brines from desalination plants in operation and affected by the progressive decrease in the activity of near thermal power plants



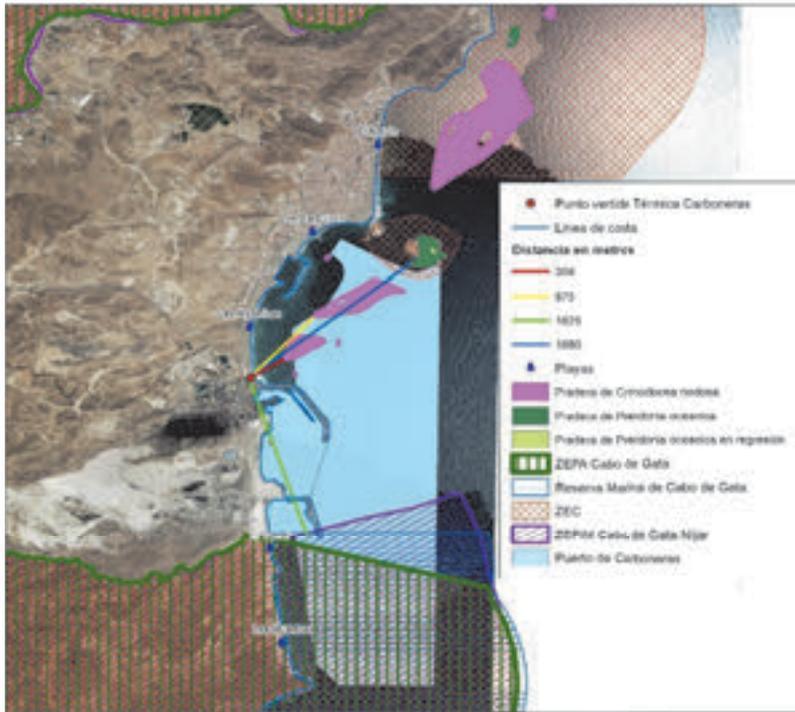
and therefore lower opportunities for pre-mixing with plant refrigeration seawater before discharge (IDAM of Sagunto and Carboneras) and also on the optimization of the environmental monitoring of discharges into the marine environment of desalination plants such as Torre Vieja after several years of operation.

Study of hydrodynamic conditions during a maritime accident.

Many CEPYC activities are driven by the necessary adaptation to climate change of the activities and space use in the sensitive coastal and marine environments. Work also been done directly in 2020 for the Spanish Office for Climate Change (OECC) through the Commission 'Support to the Impulse Plan for Adaptation to Climate Change in Spain (PLAN PIMA ADAPTA / COSTA S), 2018 – 2020' participating in the monitoring and evaluation of the activities to be carried out by the Regional Autonomous Governments in terms of the recollection of information and risk reporting.

Finally, it should be noted that the company Dragados UK commissioned several studies for the expansion of the Port of Aberdeen, UK, including wave disturbance into the new layout, construction phases of the works and the stability under extreme events of the new southern breakwater.

It should be noted and appreciated the excellent willingness of the staff and the work of the systems engineering team in this complex year in which normal activity has been strongly altered being necessary to adopt very different ways of working than usual and



Protected areas of interest in the environment of the discharge of the Carboneras desalination Plant and thermal power plant.

having to confront special difficulties in some specific work areas (experimentation, laboratory, simulation, fieldwork). This period has led to fast learning, starting in as early as April the development of a first internal remote training course; the widespread assimilation of these techniques opens up new

possibilities in particular for the CEPYC technology transfer efforts in the immediate future.

An attempt has been made throughout 2020 to maintain the presence in courses, conferences and seminars through virtual participations and it is hoped that in the future these experiences will coexist with face-to-face events necessary for maintaining an intense working collaboration with other entities in Spain and abroad.

In the last quarter of the year, an initiative has been launched for organizing, on alternate Fridays, short technical talks offered voluntarily by staff from different units. Each talk describes a specific work already done or in development and is followed by a colloquium between the attendees. This provides a broad view of the Centre's activity beyond the structural perspective and promotes an enriching dialogue, towards greater transversal cooperation and project orientation. Seven such sessions have been developed in 2020 with 10 interventions on topics as varied as the Ebro Delta Protection Plan, the Operation and Programming of Ship Access Operations in the SW basin of the Port of Palma de Mallorca, the Physical Model testing for the reconstruction of the west entrance Beacon of the Port of Pasaia, the use of the SPHERIMENTAL numerical model (developed at the Center for Hydrographic Studies, CEH of CEDEX) for the design of the physical model of the Sardinero overtopping study Study, the presentation of the Marine Environment Information System (INFOMAR), the description of the new maneuvering simulator systems and their application to design, exploitation and safety studies in the maritime environment and the process of development of the CEDEX Strategic Plan 2020 – 2022. It is hoped that we will give continuity to this activity incorporating external visions looking to reinforce shared strategies with the main recipients of the Activity of the Center.

CENTER FOR APPLIED TECHNIQUES STUDIES





Throughout 2020, marked by the difficulties that the COVID 19 pandemic has brought to the normal development of its activity, the Center for Applied Techniques Studies (CETA) of CEDEX has based its activity on six areas:

- Isotopic Applications Area
- Climate Change and Air Pollution
- Environmental Noise
- Environmental Restoration
- Industrial Environment
- Environmental Engineering

During 2020, specialized technical assistance has been provided to the Administration and other public and private entities. Although limited in the face-to-face due to the pandemic, but very active through the virtual media, the Staff of the Centre has continued to participate in national and international research, development and innovation projects, national and international meetings, courses and congresses, transferring knowledge through different dissemination and training activities. In addition, tutoring has been held for students in internships, both from Universities and Institutes.

The **Isotopic Applications Area** develops two lines of activity: Radiological Water Quality and the use of Environmental Tracer and Isotopes techniques in Hydrology. On the first line, CEDEX is commissioned by the Nuclear Safety Council (CSN) to develop two environmental radiological monitoring programs in the aquatic environment, through two networks of sampling stations: dense

< Duero River.

network and spaced network, in Spanish inland and marine waters. In the dense network the total alpha, total beta and beta rest activity rates, tritium activity and gamma spectrometry are determined, in samples of about ninety points distributed throughout the national hydrographic network and in fifteen seawater points. The spaced network determines the activity of cesium-137 and cesium-134 at two points of inland waters and two seawater points. The work is integrated within the Spanish Environmental Radiological Monitoring Network (REVIRA), managed by the CSN, in compliance with Articles 35 and 36 of the Euratom Treaty by the Member States. REVIRA results are made public in the CSN information system: <https://www.csn.es/kprgisweb2/index.html?lang=es>.

Regarding the techniques of Tracers and Environmental Isotopes in Hydrology, the Area works mainly on their application to water management and hydraulic infrastructures. In 2020, the application of these techniques to reservoir sealing studies (Tous, Bellús) for the Júcar Hydrographic Confederation was highlighted. In the Tous reservoir, the result of the work ensures the sealing of the geological substrate of its right stirrup by not having found the presence of water from the reservoir water in the groundwater of the nearby piezometers and springs selected for the study. The indicators used to unequivocally identify the presence of reservoir water have been excess deuterium and tritium activity, interpreted in an integrated manner with continuous hydrometry records. In the Bellús Reservoir, the study of the potential water condition of the

Albaida River Valley downstream of Bellús Reservoir (Photo: Silvino Castaño Castaño).



Wind turbine blades in the Port of Motril, Granada. Ports as logistics centers to support the construction of wind farms.



reservoir in its environment has continued, especially to protect groundwater supplies downstream. An R&D&I project “Innovation in the application of environmental tracers and isotopes in hydrology” has also been initiated, which aims to study the latest techniques of tracing, dating, spatial modeling, geostatistics and mass balance developed in recent years and test their application to the work and commissions that are presented to CEDEX in this field.

The Isotopic Applications Area has taught the Webinar “How old are groundwater?”, organized by the Illustrious Official College of Geologists, on April 13, 2020, which had more than 100 participants from Spain and several Ibero-American countries.

The **Climate Change and Atmospheric Pollution Area** is working on the development of methodologies to advance towards the decarbonization of activities related to transport infrastructures, as well as initiatives that promote energy savings and sensitivity to actors involved in practices that reduce their energy consumption and, consequently, emissions of greenhouse gases (GHGs) and other polluting gases into the atmosphere.

Following the development of the Methodological Guide to the Calculation of the Carbon Footprint in Ports, by 2020 its contents have been revised, incorporating the method of calculation of pipe transport and other updates of interest, whose objective is to serve as a tool to support the Port Authorities. In addition, CETA has maintained the collaboration with State Ports (PE) and different Port Authorities for the application of the calculation to an Inventory of Emissions to the Atmosphere in the port of Cartagena. These tools support the implementation of operational modeling of atmospheric pollutant dispersion within the SAMOA project (Meteorological and Oceanographic Support System for the Port Authorities included in the project), in each of the ports participating in the project and managed by these authorities.

The aim is to obtain operational modelling of the dispersion of air pollutants in ports, assessing the contribution in air pollution of port

activities in cities near ports, resulting in the improvement and management of port operations and citizen health. In the umbrella of reducing the carbon footprint, a green public purchasing manual has been developed, detailing the concept of carbon footprint in port environments.

In the field of adaptation to Climate Change, a “Methodological Framework for Climate Change Adaptation Analysis of Transport Infrastructures” has been developed, the suitability of which is being discussed within the ATC (Technical Road Association). The group is participated by CETA, the Transport Center (CET), territorial road demarcations, the Autonomous University of Madrid (UAM), with cost-benefit analysis (ACB) studies and engineering companies specializing in slopes.

Within CEDEX, the Organism’s 2020 carbon footprint has been calculated following the *Ghg protocol* methodology, with scope 1+2. This tool allows to identify the sources and magnitude of emissions at the organization level and thus reduce energy costs and GHG emissions, contributing to the fight against climate change. It also includes an Improvement Plan, which proposes the measures to be implemented to reduce the carbon footprint in the next time horizon.

The CETA **Environmental Noise Area** has continued in 2020 to work on the assessment and management of environmental noise, dedicating much of its activity to the development of methodologies for the communication of environmental noise data within the framework of the technical collaboration provided to MITERD and the Competent Authorities on noise, and the development of the legal requirements established from the European Commission for

Strategic noise map of Málaga agglomeration.



the preparation and submission of data from the Strategic Noise Maps and Noise Action Plans in the fourth phase of compliance with Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 on environmental noise assessment and management. In addition, it has carried out, among other tasks, the analysis of compliance with the third phase of the Noise Directive by the competent authorities of the Kingdom of Spain, the development of guidelines for the elaboration and communication of maps and plans, in accordance with the new data model for the reporting of results in Europe (Repornet 3.0) of maps and plans, in accordance with the new data model for the reporting of results in Europe (Repornet 3.0) and the participation, as advisors of The MITERD to the meetings of the Noise Expert Group and Noise Regulatory Committee, where the new European regulations on Environmental Noise are discussed and approved.

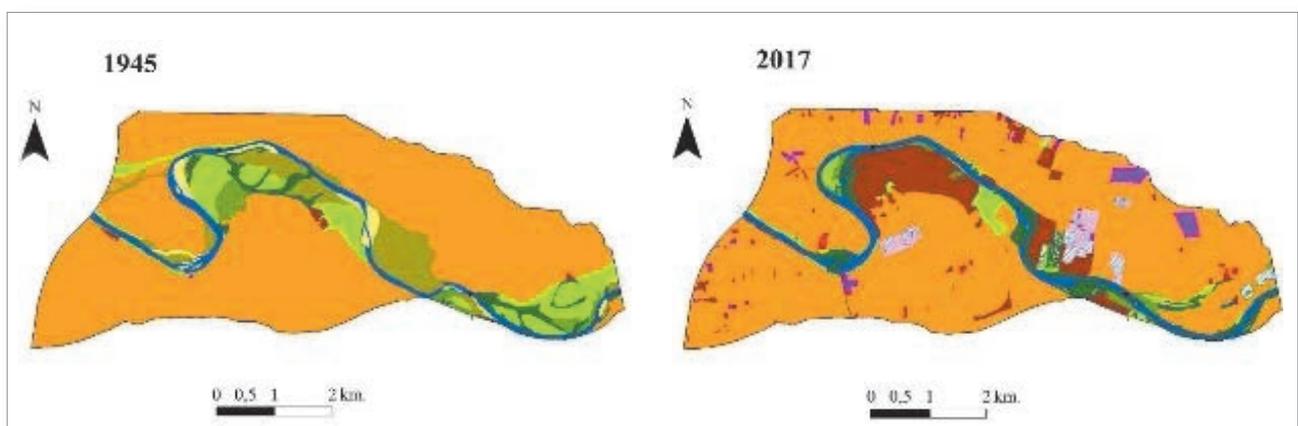
In addition, work has continued on the maintenance and development of the Acoustic Pollution Information System (SICAWEB) page: <http://sicaweb.cedex.es/> and the Spanish Environmental Noise Spatial Data Infrastructure (IDE-SICA) project has been initiated, in accordance with the requirements of the legislation on spatial data infrastructures.

Among the dissemination activities, it has participated in the National Acoustic Congress 2020 (Tecniacustica'20) with two communications.

The **Environmental Restoration Area** works on the design and monitoring of ecological restoration actions in degraded ecosystems, mainly in the river area. Its working methodology consists of the geomorphological, hydrological and ecological characterization of the field of study, the interpretation of results obtained and the design of alternatives of action according to the objectives pursued by the project.

In 2020, the Area completed the "Study of alternatives for the integral restoration of the Vinalopó River (Alicante)", as the result of the cooperation agreement signed between the Generalitat Valenciana and CEDEX, and supported by the Directorate General of Water (DGA) and the Hydrographic Confederation of Júcar.

Detail of the maps developed on ecohydromorphological processes (years 1945 and 2017).





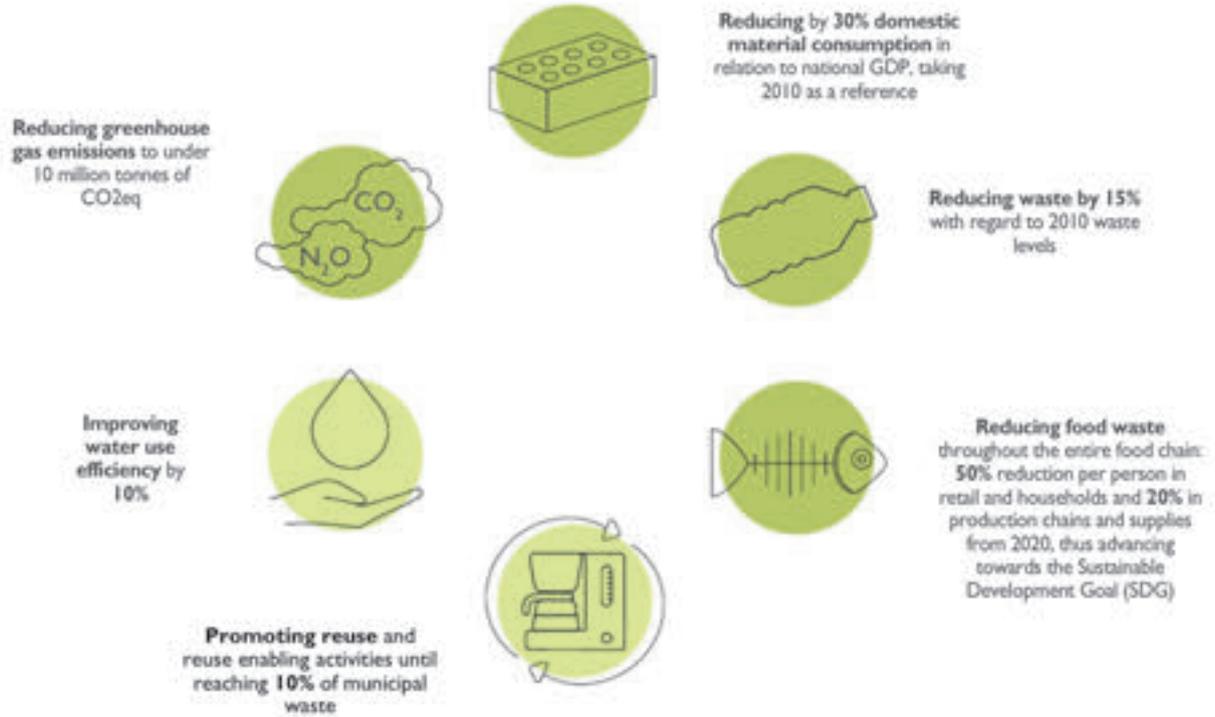
“Technical assistance in monitoring ecological flow regimes and their relationship to ecosystems” has also been provided to the DGA, a line of work expected to continue in the coming years. Finally, decisive progress has been made in the DRAINAGE project. In this sense, drone flights have been carried out for the topographical survey of the entire study section (approx. 40 km) and detailed maps have been developed on the ecohydromorphological processes that have occurred from 1945 to 2017.

The **Industrial Environment Area**, which began its activity in 2019, has focused its activity in 2020 on works related to the circular economy, where it has participated in collaboration with MITERD in the elaboration of the action plan for an effective transition to the Circular Economy. In addition, it has begun to develop its first actions in relation to the Industrial Emissions Directive in order to establish links with MITERD.

Finally, it has continued to participate, with the limitations inherent to COVID19, in the meetings of the UNE Technical Committee for Standardization (CTN 323 Circular Economy).

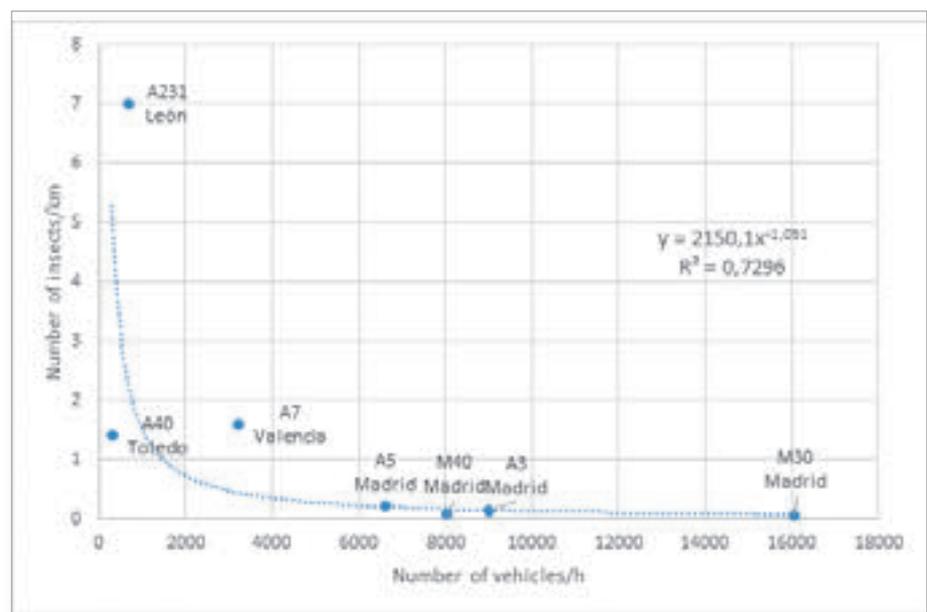
The **Environmental Engineering Area** continues to develop the Roads and Pollinators project, which analyzes the impact of roads on pollinators in the double aspect of the roadside effect and the direct running over of insects by vehicles. Sampling analyses show

Goals of the Circular Economy Strategy for year 2030.



that increasing traffic reduces the abundance of insects on the roads. Even if the number of hit-and-runs per vehicle is lower, the total number of hit-and-runs may increase when there is more traffic.

A model of hit-and-run of pollinating insects is being developed according to their behavior regarding the highway. Territorial insects (bees, bumblebees, wasps) efficiently exploit the territory and when the width or intensity of traffic increases these insects reduce, until they completely override the crossing of large infrastructures. Other groups of insects such as dipterans (including some highly



Scatter plot depicting the number of insects collected versus traffic volume.



pollinators, such as hoverflies and bombylides) occupy the territory randomly, so increasing traffic proportionally increases the number of hit-and-runs.

With the aim of increasing biodiversity and improving ecological connectivity, guidance criteria are being established for the large-scale restoration of natural or semi-natural linear vegetation elements, improving agricultural production in the highway environment from the intensification of ecological processes, which constitute solutions based on nature (SbN), applying dynamics or processes of nature itself to manage and protect natural environments or restore modified environments.

Field survey along the Duero River, during the Environmental Restoration works.



MD-201 stretch in Edmonston, Maryland. The 2019 top image features the same structure as the 2008 image on the bottom, but the median has been conditioned with vegetation that offers pollinators new spaces and resources (own elaboration on Google Maps Street View images).



CENTRAL LABORATORY FOR STRUCTURES AND MATERIALS





In 2020, the Laboratorio Central de Estructuras y Materiales (LCEYM) has accomplished a good deal of activity despite the outbreak of Covid-19, which especially affected the execution of inspections and fieldwork campaigns, given the mobility restrictions during the year.

This notwithstanding, a total of 43 technical reports were issued on high-level technical assistance, experimentation, and research and development work in the field of civil engineering and building structures and construction materials, for different organizations in the public and private sector.

On the other hand, 2020 has seen the taking on of new contracted R&D&I personnel, with the aim of experimenting with new emerging technologies. Among these, the implementation of BIM technology for the modelling of buildings and civil engineering constructions, as well as consolidating the activity of the LCEYM for the coordination of the operation of drones, so as to promote their use for inspection and data collection by CEDEX's centres and laboratories.

Among the actions carried out, those related to pathology studies and state evaluation of all types of structures stand out, with increasing activity in relation to dams and port dikes, with the aim of analysing their current state and future evolution, defining measures for their repair, and advancing the improvement of the applying regulation.

The LCEYM has continued its permanent activity of participation in the development of technical regulations, highlighting the work of preparing a practical guide for the inspection and monitoring of ponds for the Directorate-General for Water.

< Bridge with metal structure.

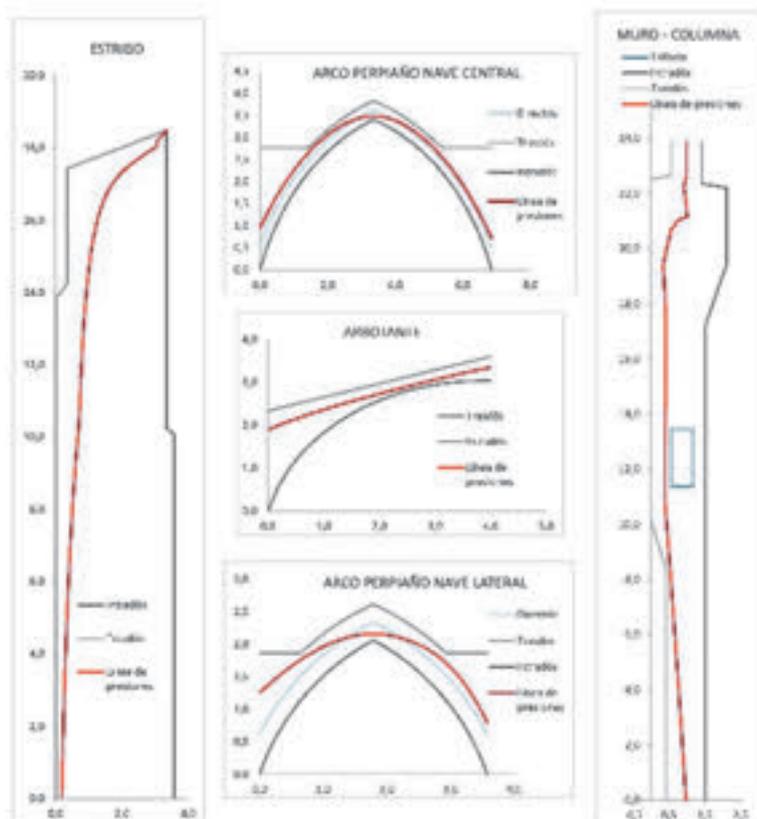
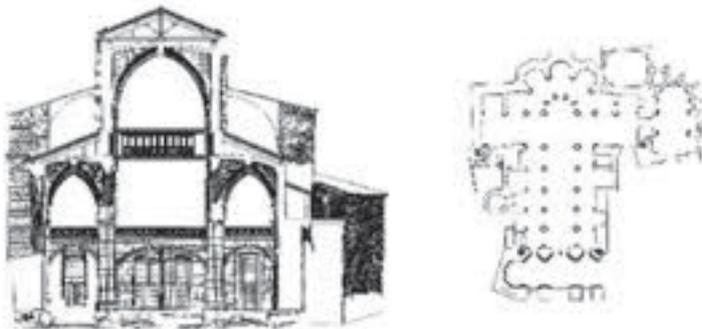
Additionally, participation in numerous material standardization and certification committees has been maintained, which has led to the issuance of 58 tariff files for various petitioners, as well as the keeping of the Secretaría de la Asociación Internacional de Estructuras Laminadas y Espaciales (IASS), which the LCEYM maintains since its creation.

The **Area for Structural Studies and Monitoring** coordinated, on behalf of Obras de Madrid, Gestión de Obras e Infraestructuras and the Directorate-General for Emergencies of the Community of Madrid, a multidisciplinary study on the damage to the concrete pavement of the new Alcobendas fire station. Besides the Central Laboratory for Structures and Materials (LCEYM), the Centre for Transport Research (CET) and the Geotechnical Laboratory (LG) participated in this study.

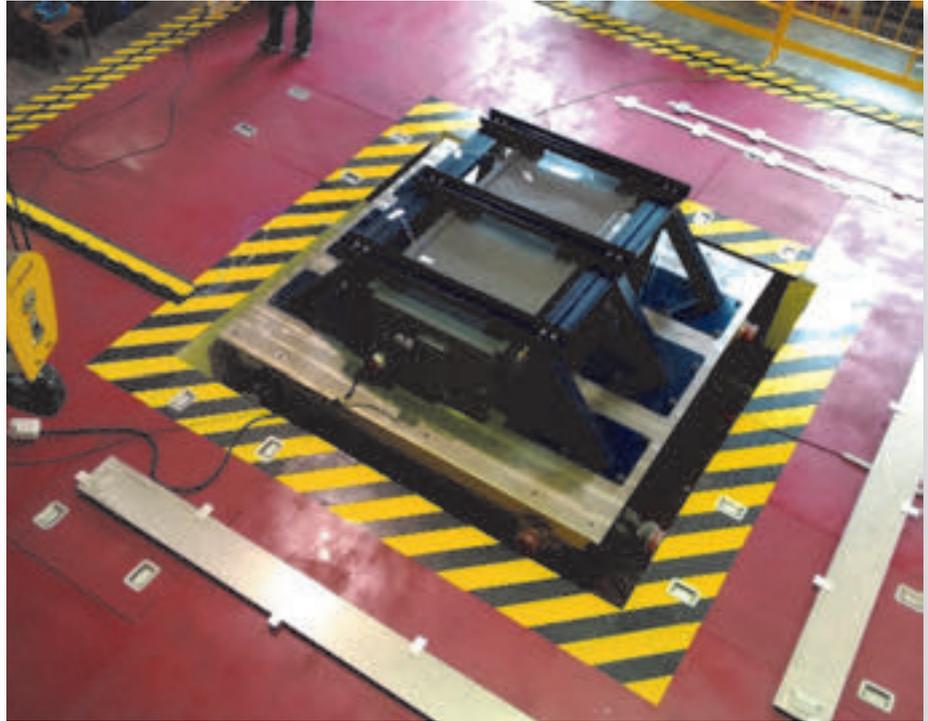
Three research projects associated with temporary staff contracts were also launched. The first of these lines of research deals with the implementation of BIM methodology in existing building and civil engineering constructions by means of 3D scanning and



Among the actions carried out, those related to pathology studies and evaluation of the state of all types of structures stand out, with recent activity in relation to dams and port docks.



Study of thrust lines in a section of the Vitoria cathedral.



subsequent modelling. The following line of work reinforces CEDEX's drone operator, developing and extending the applications of this technology, for different uses, within CEDEX's centres and laboratories in the fields of civil engineering, building and environment. Through the last of the research projects, the development of a structural assessment method for historic masonry constructions has begun.

Also, technical support continued to be provided for the conservation and structural maintenance of CEDEX's facilities. Participation in international conferences, and publication of articles in specialised journals in the fields of structures, structural pathology and historic buildings have been encouraged.

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With the seismic simulator, it's been executed the calibration of some sensors SILEX-type accelerographs, whose technology is being developed at the National Geographic Institute.

In the **Area of Structural Dynamics**, several vibration, shock and frequency sweep tests have been performed in the Seismic Simulator. Two tests stand out, an on-board radar equipment in accordance with *MIL-STD 167-1A Mechanical Vibrations of Shipboard Equipment* standard, as well as a prototype of an auxiliary converter equipment that will be embarked on trains in accordance with *IEC 61373: 2010 Railway Applications-Rolling Stock Equipment-Shock and Vibration Tests* standard. These tests have been carried out for INDRA Sistemas and ACTIA Systems companies, respectively.

The calibration of 30 accelerometer sensors called SILEX has taken place in the Seismic Simulator. The technology for this accelerometers is being developed at the National Geographic Institute (IGN).

Besides, maintenance work has started at the Seismic Simulator facilities, within the hydraulic control system, aimed at improving its



operation, stability and response during tests. To do this, the hydraulic pressure system accumulators and actuators have been checked and recharged both in the high pressure and the return line.

La Tajera dam.

In the **Area of Materials Science**, a great deal of activity has been accomplished in the field of pathology in concrete dams due to different chemical processes. During this year the study of the concrete of La Tajera dam, in Guadalajara, has been finished, on request of the Directorate-General for Water. This dam was built in the 1990s using fly ash addition in the concrete. The tests have shown the benefits of using this addition in long term concrete properties: High compressive strength and low permeability has been found in concrete cores extracted. This study will be completed next year with a specific research on delayed ettringite formation in concrete.

Recently, on request from the Naturgy hydroelectric company, the study of the concrete in the Castrelo dam, in the province of Orense, has started. In a first phase, a visual inspection of the dam and *in situ* tests have been executed.

In respect to harbour structures, a study on the corrosion of reinforced concrete of the Levante dock at Málaga port has been carried out. Works have included visual in site inspection, field tests, cores extraction, and laboratory tests. Another corrosion study of the Escombreras south-west dock, in Cartagena port, has also been completed. Furthermore, it's just started the study of Reina Sofia dock in Las Palmas port, which is expected to finish next year. All these works have been requested by the Spanish Official Port Agency Puertos del Estado. The final results of these reports will allow to reach conclusions about docks behaviour exposed to



In the field of port structures, the study of corrosion in the reinforced concrete of the Levante dock in the port of Málaga has been completed.



Caisson at anchor in the works of enlargement of Reina Sofía dock, port of Las Palmas de Gran Canaria.

severe marine environment and their service lives, improving the actual technical normative. The objective of the study is to prevent the appearance of similar problems in future docks.

Further, and also commissioned by Puertos del Estado, research on the influence of the construction of caissons using floating platform technology, widely used in our country, has kept on. The objective is to evaluate the effect of the premature contact of the caisson's concrete with seawater on the diffusion of chlorides, and the risk of corrosion of the reinforcement. The study of caissons at the port of Barcelona is well underway, and similar drillings have been planned for caissons at the port of Tenerife, which will be completed in the following year.

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

The 2020 Permanent Technical Services for Steels for Concrete and Structural Steels have executed many rated tests, with public prices, for different clients.

In this field, it should be underscored the works for certification committees within the framework of the AENOR Certification Commission.

These activities require many laboratory tests for determination of physical, chemical and mechanical properties, as well as the ENAC accreditation and the Quality Management System according to UNE-EN ISO/IEC 17025:2017 standard.



Stress relaxation test equipment.

In order to keep the ENAC accreditation for tests as an external organization, quality assurance tasks, verifications, interlaboratory comparisons and calibrations have been made, in addition to studies on uncertainties, precision and accuracy of test results.

For the AENOR quality mark, the line of test on malleable cast iron elements for pipes has also gone on.

After the launch of specific fatigue tests for ADIF and other railway suppliers, these same tests have been carried out on loadbearing steel sections and communication beacons.

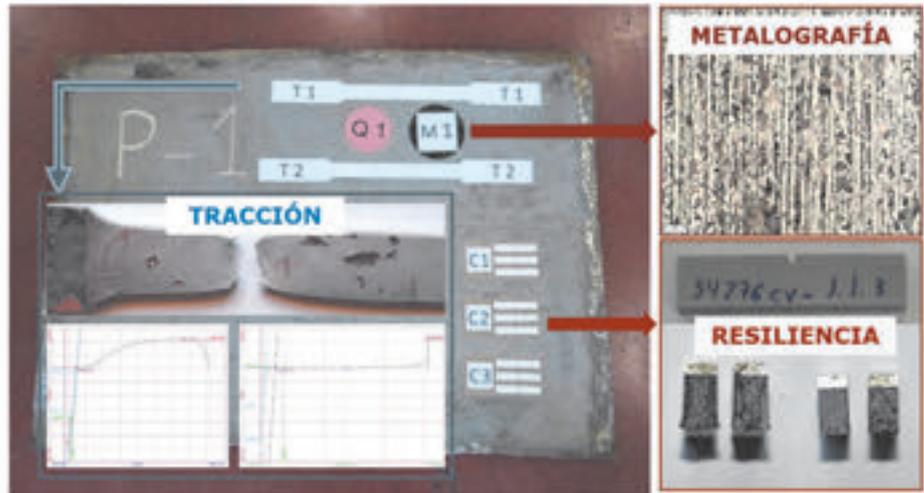
Forensic engineering studies on metallic elements of existing structures in service have continued. For the Directorate-General for Water, the study of the pathology of the substituted gates of the San Juan dam, in Madrid, has finished.

In the **Area of Materials**, within the reservoir waterproofing field, works concerning the collaboration agreement with Balsas of Tenerife and the Insular Water Council of La Palma, as well as with the Taibilla Canals Community, have continued. These works are carried out for the study and monitoring of the performance of



Steel reinforcement of concrete fractures.

Scheme of tests for characterizing structural steel.



La Cruz Santa Reservoir.
Tenerife Island.



waterproofing geomembranes used in reservoirs. The collaboration with the Directorate-General for Water, for the preparation of the *Practical Guide for the Inspection and Monitoring of the Geosynthetic Barriers Used in the Waterproofing of Reservoirs*, has also carried on.

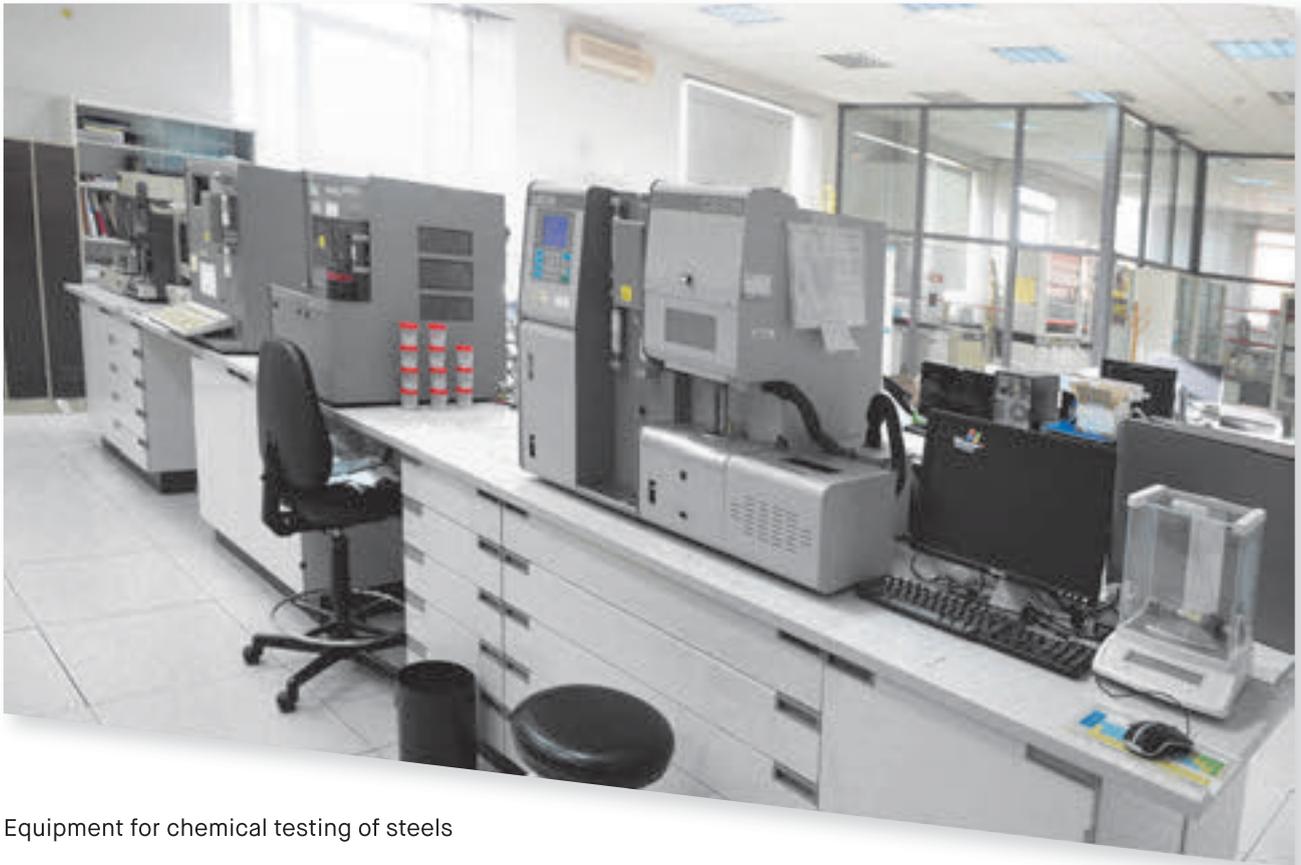
Moreover, the LCEYM-Construction Products Area has kept on with chemical testing of steels. These tests are accredited by the National Accreditation Entity (ENAC), and are performed by means of optical spark emission spectrometry, melting furnace with detection by measurement of thermal conductivity, and induction furnace with infrared detectors.

Likewise, tests have been performed to study various pathologies of concrete, such as the determination of chloride profiles and the mineralogical analysis by X-ray diffraction.

This Area has participated in the annual programs of inter-laboratory tests organized by the Secretariat of the Technical Committee for the Certification of Cement AE/CTC-015.

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The chemical tests of steels continue to be carried out by the Area of Construction Products.



Equipment for chemical testing of steels

In the field of road signals and marks, a large number of reports have been issued for the verification of indicators regarding retroreflection of road markings and vertical signals. Thus implementing the order in its own means embodied in the Directorate-General of Roads of the Ministry for Transports, Mobility and Urban Agenda for technical assistance in the verification and checking of the indicators used in the highway contracts (2018-2021). The work regarding the agreement with 3M España S.L., for the study of the behaviour of different microprismatic retroreflecting materials for vertical signals, has continued.

The LCEYM is recognized by ENAC in the Quality Management System (QMS), UNE-EN ISO/IEC 17025 Standard, as a testing laboratory in the fields of physical-mechanical and chemical metallic materials tests. An Internal Calibration Unit for dimensional and weighted type is also operating, with ENAC traceability. Between April and July 2020, an external follow-up audit was evaluated by ENAC. It was done remotely due to Covid-19, which implied a quickly adaptation to the new technologies. The QMS activities will be evaluated by ENAC in October 2021.

Up to 29 quality documents have been updated, to adapt them both to the new requirements of ENAC documents, the new codification of the quality systems, and to digital signature. In addition, the remaining testing technical documents are going to be revised to comply with the new version of Products and Testing Standards.

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Testing has been performed for the study of various pathologies of concrete, such as the determination of chloride profiles and mineralogical analysis by X-ray diffraction.

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The programmed environmental objectives have been achieved. Environmental aspects, legal requirements, risks and improvement opportunities have been identified and evaluated.

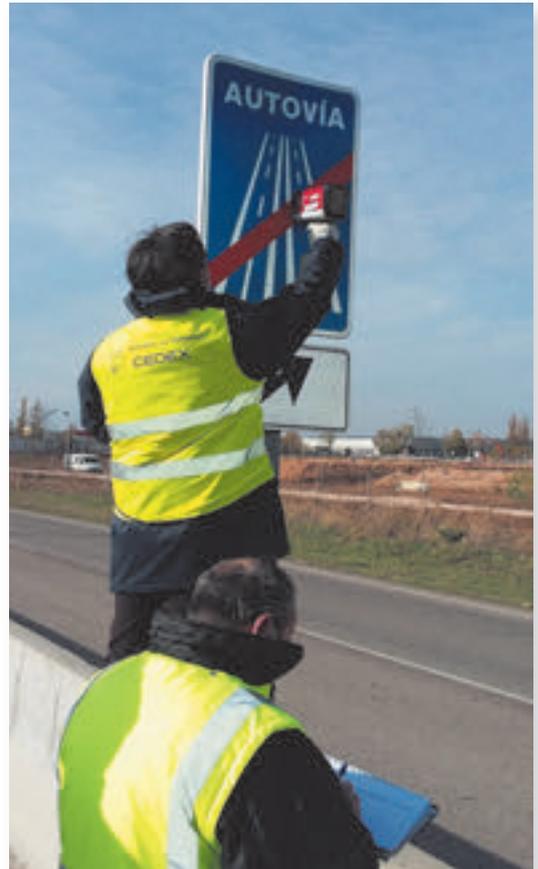
The 6 databases in Access, which register the QMS activities, and the server Q (the computer archive for QMS documents registry), have been maintained and updated. The QMS documents has been relocated in a new server, reinstalling access and editing permissions.

The LCEYM maintains internal auditors' team to perform internal audits, and coordinates the maintenance of the 3 files currently present at CEDEX (CETA, LIF and LCEYM).

The LCEYM is part of the CEDEX Multisite Certification of the Environmental Management System (EMS) UNE-EN ISO 14001, to commit, through its EMS, to the observance of the Sustainable Development Goals (SDGs) and the Green Deal. The external audit was performed by the Certification Entity SGS in November 2020.

In the same way, environmental goals have been achieved. Environmental aspects, legal requirements, risks, and improvement opportunities have been identified and evaluated. The energy performance of the building has been assessed. It's continued the raising of awareness of environmental issues in the workplace.

Lastly, it's been initiated the creation and implementation of the server M (the computer archive for EMS documents registry) and the use of the Excel book to register of EMS results.



Measuring retroreflection of vertical signals in highway A-4 section 3.

GEOTECHNICAL LABORATORY





GEOTECHNICAL LABORATORY

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Within CEDEX, the Laboratorio de Geotecnia (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) ground and geotechnical issue investigations, by laboratory, field and auscultation techniques; 2) analysis, through analytical and numerical calculations, *in situ* or full-scale testing and geotechnical observation; and 3), improvement on safety works, by geotechnical reports with recommendations on project solutions, correction of malfunctioning or damaged engineered sites or construction methods for specific works, or through the development of guides and technical manuals.

In 2020, the activity has focused mainly on geotechnics of roads, railways and ports and coasts, as well as on environmental and geotechnics on hydraulic structures. 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: Dirección General del Agua [DGA], Confederaciones Hidrográficas, Costas, Calidad Ambiental [DGCEA]); work has also been carried out for autonomous communities, private companies and for the European Union (R&D projects; CEN).

Despite the halt in non-essential activities due to the quarantine caused by Covid-19, civil servants, in particular, didn't temporarily interrupt the activity except for certain necessarily *in situ* actions, such as visual inspections of works or infrastructures with geotechnical pathologies, or conducting field tests; these activities resumed normally at the end of the quarantine. In terms of human resources, in 2020 the LG had a staff of 51 employees, 23 of which are

< Rock formation of sandstone.

civil servants (16 of Group A1 with degrees in Geotechnics, 6 of whom with PhD's degree), 8 R&D workers, and 20 technical assistants.

In terms of its technological capacity, the LG has a complete set of geotechnical testing equipment and a number of unique testing devices and capabilities, among which the following can be highlighted: the CEDEX DGC 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 pressuremeter, the seismic piezocone, and the set of seismic and electromagnetic geophysical equipment. The main activities in 2020 are highlighted below, grouped by theme:

GEOTECHNICS OF ROADS

For DGC of the Ministry for Transports, the LG has carried out technical assistance studies and instrumentation work to monitor pathologies in many points of the National Road Network: Instability of a large cut slope on the A-7 motorway next to the town of Carchuna (Granada); pathologies on different roads (N-621, A-8 and A-67) of the province of Cantabria; Ramoncillos tunnels and various cut slopes on the A7 Mediterranean Highway, in the Polopos-Albuñol section (Granada); damages around the cut-and-cover tunnel of section 851 of N-420 (Coll de la Teixeta, Tarragona); cut slope (section 99.6) and embankment (section 102.5) pathologies of N-420 road in the surroundings of Fuencaliente (Ciudad Real); damages at section 83.5

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In 2020, the activity has focused mainly on geotechnics of roads, railways and ports and coasts, as well as on environmental and geotechnics on hydraulic structures. R&D, training and standardization activity has also been important.



Figure 1. Study of geotechnical road pathologies for the DGC. Bypass of Escucha (Teruel).



Figure 2. Studies of geotechnical damages on roads. Link of Canena (Jaén).

of A22 motorway and between sections 437.3 and 437.5 of A-2 in the province of Huesca; damages between sections 12+625 and 13+000 of the Burgos BU-30 Ring Road; malfunctioning observed in different sections of N-432, A-45 and CO-32 roads in the province of Córdoba; deformations and instability in several embankments in the bypass of Alcoy of A-7 motorway (Alicante); embankment geotechnical problems of the bypass of Escucha (figure 1) of N-420 (Teruel); deformations in a structure of A-33 motorway over railway in Fuente la Higuera (Valencia); damages on pavements observed in A-44 motorway in Jabalquinto and the link of Canena (figure 2) of A-32 (Jaén).

As part of the R&D&I programs developed in 2020 by the LG, it's noteworthy that new methodologies for monitoring the evolution of geotechnical pathologies such as those described are being implemented, based on the new technologies available: laser-scanner type, photogrammetry, with or without support of drones, etc.

RAILWAY GEOTECHNICS

The work of the LG covers four fields of action: 1:1 scale tests in CEDEX Track Box facility (figure 3), on-site instrumentation and testing in railway sections, modelling of railway sections, and laboratory tests on materials used in railways. Among the 2020 relevant studies, the

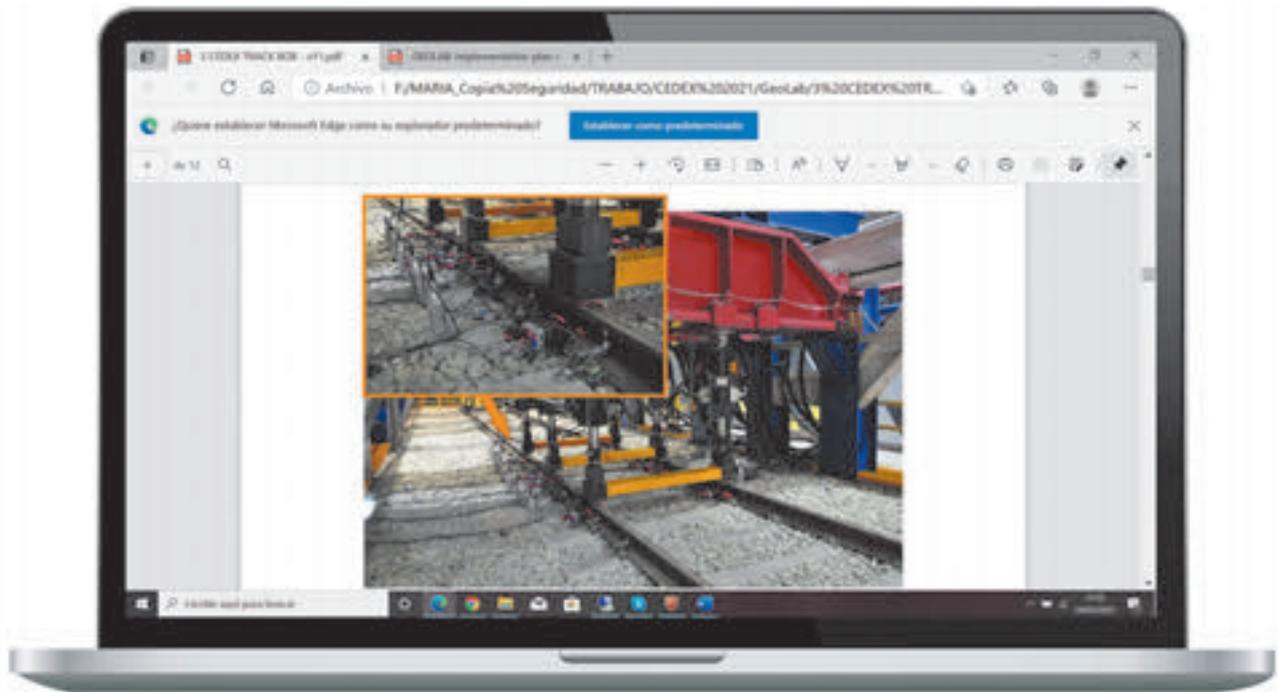


Figure 3. CEDEX Track Box facility.

following ones are worth mentioning: those aimed at meeting the commitments of our participation in the research programmes on railway geotechnics, in particular the preparation of the proposal for the participation of CEDEX in the European project GEOLAB (which has been selected by the EU and begins work in 2021); the study on fatigue tests on ballasted tracks at the pass of trains at 400 km/h; the study on methods of determining the critical speed of railway sections, including the determination of the critical speed using the method of the system dispersion curve-based, comprising railway track, fill and natural soil layers (which has resulted in a joint article with E. Kausel MIT 2020, published in *The Royal Society Proceedings*).

PORT GEOTECHNICS

Geotechnical assistance has been provided to the National Port Authority (Puertos del Estado). Thus, the support over the drawing up of the project for the new container terminal at the port of Marín has been completed; the geotechnical and geophysical campaign for the enlargement of the new container terminal and deepening of the canal of the port of Cádiz has been supervised and interpreted; also for this port, geotechnical and geophysical expertise has been put to work for legal action about a construction, as well as fieldwork to supervise the repair of major leaking through the concrete diaphragm walls of the underground access road to the new container terminal; the design of the preload on the surroundings of the dismantled thermal power plant at the port of Pasajes has been studied; an intense campaign with the Panda penetrometer, together with another with georadar and PS-Logging, have been carried out on the south quay of the port of Huelva, all aimed at gaining insight into the loss of serviceability and subsequent remediation guidelines; a review of details of the project for the extension

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Regarding R&D&I, the "study of the setting time of jet-grouting columns under port caissons, using geophysical techniques" has been issued, using experimental data at the port of Valencia.

(designed with sheet piles, figure 4) of just this quay has been made, as well as checking the contractor's FE Model against those proposed by CEDEX, and the interpretation of an additional campaign, including PS-Logging tests; besides, assistance has been provided on the foundation of a building at the maritime station of the port of Ceuta; the geotechnical campaign has been proposed for a project for the extension of another quay at the port of Avilés; support has been provided to the Port Authority of Castellón for the project of the wharf for liquid bulks at the south quay; finally, some judgement for a project with soil improvement of the backfill at quay 17 of the port of Alicante has been reported to Puertos del Estado.



Figure 4. Expansion of the southern pier of port of Huelva, by means of sheet pile walls.

Regarding R&D&I, the "study of the setting time of jet-grouting columns under port caissons, using geophysical techniques" has been issued, using experimental data at the port of Valencia. Machine learning techniques are being successfully developed for Puertos del Estado generate geotechnical profiles (from CPTu) minimizing subjective judgement.

On the other hand, work is being made to optimize field data acquisition, analysis, processing and decision-making on the go with the support of new technologies; a case of a real instrumented large port is used.

ENVIRONMENTAL GEOTECHNICS

Regarding environmental issues, the LG is working together with CEDEX's Centre for Studies on Applied Techniques (CETA) in the study "Analysis of the impact of lindane pollution from the Sardas landfill on the Gállego river" for the River Ebro Water Authority. Also in the environmental field, collaboration continues with the CETA on the study of the environmental restoration of the Vinalopó river (Alicante). A study has been carried out for the company FCC Ámbito about the "Using Construction and Demolition Waste (CDW) with gypsum in



earthworks”. This project is related to the city-planning operation “Madrid-Norte”. Another important work has been developed in 2020 to study the stability of a non-hazardous waste landfill at Yurre (Biscay).

Figure 5. Waste landfill stability study.

GEOTECHNICS OF HYDRAULIC WORKS

Technical assistance activity to the DGA has been intense in 2020, mainly in the field of dam geotechnical pathology analyses. Two works in the Tagus basin stand out: the unique large-scale permeability test performed by the LG on the upstream slope of Alcorlo dam (figure 6), and the initiation of studies on the state of the foundation of El Atance dam; and another in the Ebro basin: the diagnosis related to the appearance of moisture in Mairaga dam. Ongoing support is being provided for the updating of the instrumentation of Arenós dam, on the Mijares river (Castellón), and geotechnical information on potential sites in the lowlands of the Segura river basin is being evaluated to build several flood-control dams.

Also in the field of hydraulic works, the LG has participated in the revision of the San Silvestre Hydraulic Twin-Tunnel Project (Huelva). Likewise, it technically assists the project of the subfluvial tunnel between Santoña and Laredo, which is part of the “Santoña-Laredo-Colindres” main sewer pipe of the general sanitation network of the Santoña Bay Area (Cantabria).

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A study has been carried out for the company FCC Ámbito on the “Using Construction and Demolition Waste (CDW) with gypsum in earthworks”.



Figure 6. Large-scale permeability test (Alcorlo dam, upstream slope).

R&D&I

In the field of R&D&I, the development of the applications of geophysical techniques available in the LG is in progress. Different lines of research are being developed related to the contracts of 8 new researchers, who started working on 1 January 2020. 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 (1 researcher); development of dynamic testing on soils and ballast (1 researcher); development of geotechnical instrumentation, ground improvement and monitoring techniques for coastal-port structures (2 researchers); development of geotechnical tests for rocks and coarse granular materials (1 researcher); study of theoretical and experimental geotechnical aspects of unsaturated soil behaviour (1 researcher).

STANDARDIZATION

Work has been done on UNE's national standardisation committees, in particular the UNE Committee CTN 103-Geotechnics and Subcommittee EC-7 of Committee CTN 140-Structural Eurocodes, of which CEDEX holds the Presidency, as well as in their various subcommittees and working groups thereof. Work has continued on the drafting of the future Eurocode 7, Geotechnical Project,



Figure 7. Dynamic Simple Shear Test equipment of the Laboratorio de Geotecnia.

commissioned by CEN TC-250, through Nederlands Normalisatie-Instituut (NEN). In the railway field, work has been done on the preparation of documents for UIC (International Union of Railways) regulatory drafting committee, in particular on the drafting of UIC-IRS 70722 (*Maintenance and Improvement of Earthworks and Track Bed of Existing Railway Lines*). At the request of the General Technical Secretary of the Ministry for Transport, the LG has reviewed the geotechnical aspects of the new text of the "Safety Technical Standards for Dams and Reservoirs".

TRANSFER

In 2020 the 38th edition of the *Master's Degree in Soil Mechanics and Geotechnical Engineering CEDEX-UNED* was held, with 15 students from different countries. Because of the outbreak of Covid-19, the on-site classes had to be cancelled on February 13, and shifted successfully to on-line mode after acceptance by the students, thanks to the efforts of the course coordinators, without lowering of teaching standards. An important effort has been made to maintain the presence of CEDEX in national geotechnical forums: Spanish geotechnical societies, AENOR standardization committees; internationally, changing the mode of participation to online modalities: participation in international geotechnical standardization committees and working groups (European standardisation committees CEN), ELGIP platform, organization of several in-person technical conferences (*SEMSIG-AETESS Technical Conferences* in March) and virtual attendance to on-line conferences, being specially remarkable a presentation on the Master's Degree in Soil Mechanics and Geotechnical Engineering at CEDEX-UNED at the *International Conference on Education in Geotechnical*. The LG hosts the Secretariat of the two main geotechnical scientific societies nationwide: the Spanish Society for Soil Mechanics and Geotechnical Engineering (SEMSIG) and the Spanish Society for Rock Mechanics (SEMR), and has put on the activities organised by these two societies.

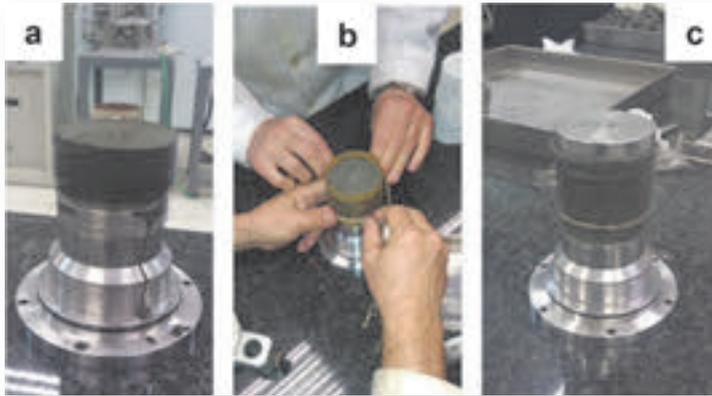


Figure 8. Dynamic simple shear liquefaction testing for MATSA. (a) Sample prepared with the dimensions necessary for the test. (b) Membrane placement. (c) Placing the top plate.



Figure 9. Sample of material from a non-hazardous waste landfill for testing in the 1 x 1m direct shear box.

LABORATORY STUDIES

Geotechnical tests have been carried out through the Permanent Technical Service for different domestic and foreign clients. Laboratory tests have also taken place within the framework of different contracts and research projects (figures 7 to 10). In 2020 more than 10 reports of completed works have been issued, highlighting those made for line 11 extension of Madrid Underground, and for the Almodévar reservoir. In the chemistry section, tests have been undertaken for 6 different studies: Collaboration with the LCEYM (La Tajera dam, study on the concrete of Atance dam, copper smelting slag leachates); and with the Centre for Transport Research (CET) (rubber dust leachates), as well as work within the European Technical Committee CEN TC 396. Regarding the dynamic testing section, for MATSA-Aguas Teñidas, 18 dynamic simple shear tests, resonant column tests and Bender element tests have been performed. Work is underway for the University of Córdoba of soils with nano-material. Studies have been implemented to establish the testing procedures for dynamic simple shear test equipment, adapted to the new *ASTM D8296-19: Standard Test Method for Consolidated Undrained Cyclic Direct Simple Shear Test under Constant Volume with Load Control or Displacement Control*. And direct tension test methods on rock samples are being also developed.



Figure 10. IC ion chromatography equipment of the chemistry section of the Laboratorio de Geotecnia.

CENTRE FOR HISTORICAL STUDIES OF PUBLIC WORKS AND URBAN PLANNING





Since its foundation, over 30 years ago, the Centre for Historical Studies of Public Works and Urban Planning (CEHOPU), of CEDEX, has developed its activities according to its fields of competence, through the organization of exhibitions, publications, and participation in congresses, conferences and meetings, all with the aim of researching, studying and disseminating the important historical heritage of public works in Spain.

The historical evolution of engineering, urban planning and public works, and its patrimonial legacy, have been embodied not only through the organization of the exhibitions presented by the centre, but also in the construction of the Collection of Models of History of Public Works, which constitutes a singular collection of elements, maintained and managed by CEHOPU.

The exhibitions and models, along with the list of publications and the rich collection of images and books in the graphic archive and the specialized library of the centre, represent the main asset which, with a significant financial effort, has been bolstered throughout this extensive period of activity.

At present, and in a context of cutbacks, it seems timely to put in value these collections that constitute, in their own right, valuable assets to hold the work of the centre up to standards.

The activity of the centre in 2020 has been affected by the pandemic situation that has plagued the country.

The areas of activity in which the CEHOPU organizes its tasks have been affected to a greater or lesser extent by this situation, and depending on the different degrees of confinement, the limitations to our activity derived from teleworking, the restrictions on national and

< Detail of the bridge in Mérida over the Guadiana river under construction.
Carlos Fernández Casado Archive. Id.: I/FC-049/055.

COLLECTION OF MODELS ON THE HISTORY OF PUBLIC WORKS

Around 500 models make up the current balance of this important and constantly growing collection on the history of engineering. Its contents form part of the different exhibitions held by CEHOPU, as well as the thematic collections produced all along its activity. In the images, models of the Aqueduct over the river Najerilla, in La Rioja, and the Pile Driving Machine, both of which belong to the collection.

The first one, the work of Carlos Fernández Casado, serves as a support for the conduction channel for the hydroelectric exploitation of the La Retorna waterfall. The hydraulic complex is complemented by a 14-metre-high-arch dam and another smaller aqueduct.

The second one, for its part, represents a device traditionally used for the installation of piles in harbour or river environments, the pile driver. Foundations under water, or in swampy or waterlogged ground, have a long historical tradition and are perhaps the most complicated construction problem to be solved by means of stakes driven into the ground.



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The exhibitions and models, together with a long list of publications and the extensive collection of images from the graphic archive and books from the centre's specialized library, represent the main accomplishment that, with a significant economic effort, has been achieved in almost 40 years of activity.

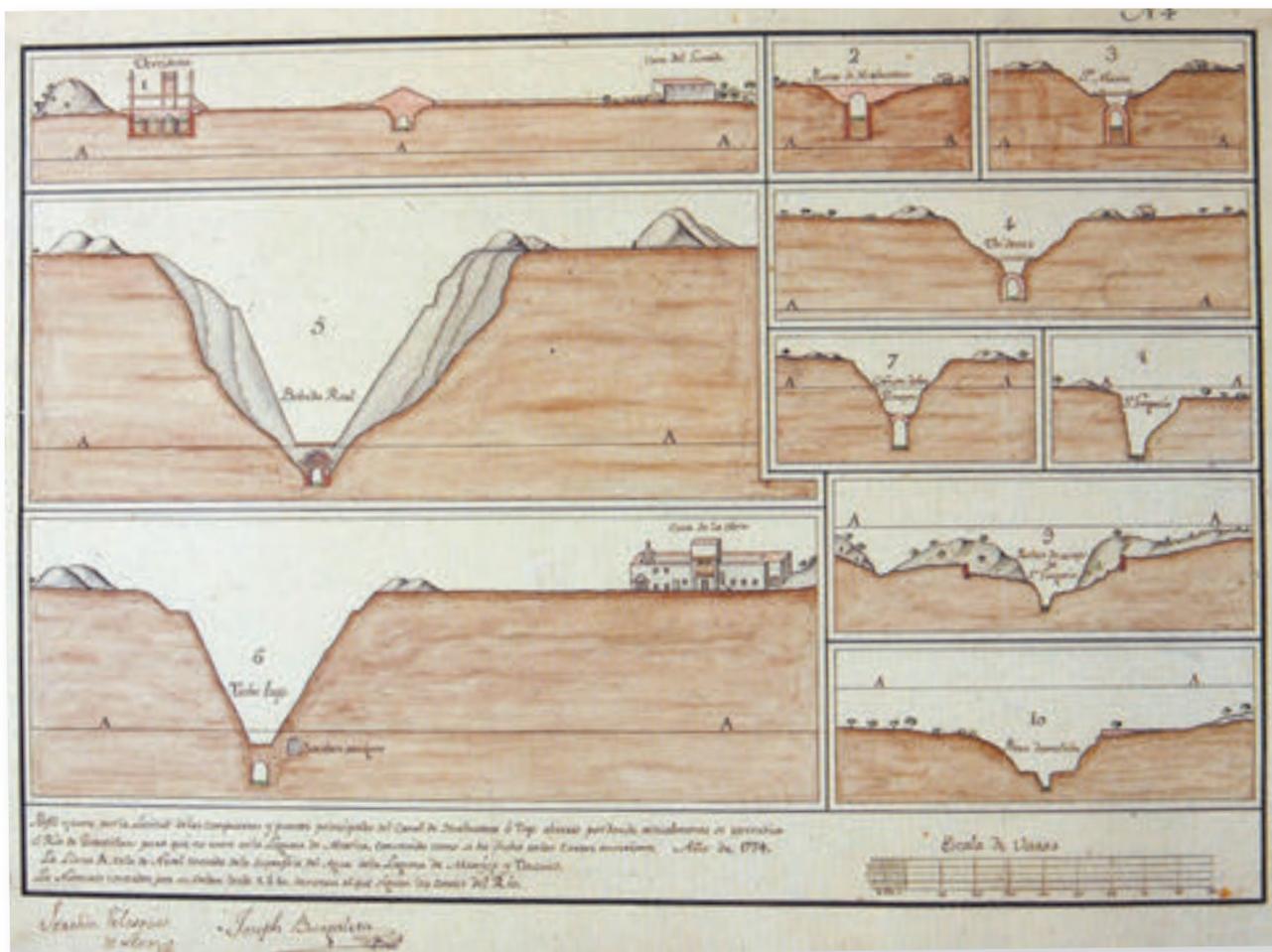
JUAN GARCÍA HORTELANO LIBRARY AND GRAPHIC ARCHIVE

The Juan García Hortelano library is named after the engineer and writer who, as a civil servant, served at CEHOPU. It specialises in the history of public works, engineering, technology, construction, town planning and its heritage, and has a collection of 8,000 books.

Besides, the CEHOPU has a photographic archive for internal use, the outcome of the work carried out by the centre since its inception. It currently contains more than 40,000 images and is constantly updated, bringing in new material collected in recent years, which involves cataloguing, classification, inclusion in the database, signposting and other necessary actions, as well as a process of total digitisation of the archive's holdings.



international travelling, and also on the reduction of activity and hours of archives and museums. On top of that, it should be added the cancellation or reduction of all kinds of public and face-to-face events, such as the opening of exhibitions, conferences, meetings, etc.



Cross sections of the pit works. Huehuetoca drain 1774. México. CEHOPU Graphic Archive. AGN, 3672.

Even so, and when it comes to the travelling exhibitions, the one called *Santo Domingo de la Calzada. El Ingeniero del Camino* came to an end in January 2020 at the Exhibition Centre of the San Francisco Convent, in the Riojan town of the same name, after having extended its duration for the notable success and the large number of visitors, who could enjoy the engineering works related to the Saint on the Way of St. James as the Jubilee Year of Calceatense was drawing to a close, which was added to the celebration of the millennium of the birth of the saint.

Activities in regard to travelling exhibitions have undoubtedly been hit worst for the aforementioned reasons. In addition to the difficulties arising from the restrictions on interprovincial movements, the lockdown of the population has entailed the impossibility of carrying out all kinds of public events.

However, a good deal of requests have been made, which will be laid out throughout 2021 and beyond:

- *Artifex. Roman Engineering in Spain.*
Santo Domingo de la Calzada (2021).
- *Ars Mechanicae. Medieval Engineering in Spain.*
Santo Domingo de la Calzada (2022).
- *Ildefonso Sánchez del Río. The Power of a Legacy.*
Santo Domingo de la Calzada (2023).



Puente la Reina Bridge. Model of the bridge Puente la Reina. Sculpture of the Saint Surveyor.

- *Félix Candela. The Achievement of Slenderness.*
Exhibition Hall of the Official College of Architects of Madrid (2021).
University of Oviedo. Polytechnic School of Mieres.
- *Spain in the Mediterranean. The Construction of a Space.*
Government Delegation in Catalonia.
- *Arc Bridges in Spain.*
Government Delegation in Catalonia.
University of Oviedo. Polytechnic School of Mieres.
- *Beyond the Arch. Straight Bridges.*
Government Delegation in Catalonia.
- *Iribarren. Engineering and Sea.*
Oviedo University. Polytechnic School of Mieres.
- *Philip II. Artefacts and Machines.*
House of Sciences. Logroño City Council (2021).
- *Santo Domingo de la Calzada. The Engineer of the Road.*
Castilla-La Mancha Demarcation of the College of Civil Engineers (2021).

Different collaboration proposals have also been received for various events:

- Exhibition *Burgos, 1921: When the Cathedral Celebrated Its 700 Years*, organized by the Eighth Centenary Foundation of the Cathedral (2021).
- Exhibition *Fortification, City and Construction*, organized by the Juanelo Turriano Foundation (2021).
- Exhibition *Castilla-La Mancha and Civil Engineering*, Demarcation of Castilla-La Mancha of the College of Civil Engineers, Canals and Ports (2021).

Researching is the mainstay that supports CEHOPU's different projects, which are materialised in exhibitions and publications.

Two major exhibitions will be held in 2022 and 2023:

Science and Water. Manuel Lorenzo Pardo. Hydraulic Engineer (1881-1953).
Villanueva Pavilion of the Botanical Garden of Madrid.

The Urbanism of the Enlightenment. The Founding of Cities in the 18th Century.
Showing Rooms of the National Library of Spain, Madrid.

Chorography of the Tagus River. Navigation of the Tagus River between Toledo and Alcántara. 17th century. Royal Academy of History. Exhibition *Philip II. Artefacts and Machines*.



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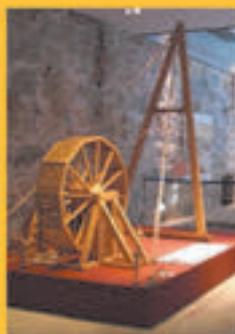
The exhibition *Santo Domingo de la Calzada. El Ingeniero del Camino* came to end in January 2020 at the Exhibition Centre of the San Francisco Convent, in the Riojan town of the same name, after having extended its duration for the notable success and the large number of visitors, who could enjoy the engineering works related to the Saint on the Way of St. James.

CEHOPU TRAVELLING EXHIBITIONS

CEHOPU's travelling exhibitions bring its contents closer to the general public through the different openings that take place throughout Spain and abroad.

They're the result of putting together specially adapted packages of the original exhibitions inaugurated at the time. Currently, there are eighteen exhibitions in this travelling collection, some of which are subject to maintenance and even transformation in order to reduce transport and assembly costs.

- SPANISH PORTS THROUGHOUT HISTORY
- BETANCOURT. THE ORIGINS OF MODERN ENGINEERING IN EUROPE
- ARTIFEX. ROMAN ENGINEERING IN SPAIN
- IRIBARREN. ENGINEERING AND SEA
- MANILA 1571-1898. WEST ENCOUNTERS EAST
- CANAL OF CASTILLA
- IMPERIAL CANAL OF ARAGÓN
- KING PHILIP II OF SPAIN. ARTEFACTS AND MACHINES
- COLLECTION OF MODELS OF THE HISTORY OF PUBLIC WORKS
- ARS MECHANICAE. MEDIEVAL ENGINEERING IN SPAIN
- ILDEFONSO SANCHEZ DEL RÍO. THE POWER OF A LEGACY
- FÉLIX CANDELA. THE ACHIEVEMENT OF SLENDERNESS
- TORROJA
- CARLOS FERNÁNDEZ CASADO, AN ENGINEER
- SPAIN IN THE MEDITERRANEAN. THE CONSTRUCTION OF A SPACE
- ARCH BRIDGES IN SPAIN
- BEYOND THE ARCH. BRIDGES OF MODERNITY
- ENLIGHTENMENT HYDRAULIC WORKS



SCIENCE AND WATER EXHIBITION. MANUEL LORENZO PARDO. HYDRAULIC ENGINEER (1881-1953)

Manuel Lorenzo Pardo is undoubtedly a key figure in the field of civil engineering in Spain. His activity transcended the scope of his profession, imprinting a scientific character on all his achievements, forming part of the so-called generation of wise men, who promoted the taking-off of Spanish science at national and international levels, based on the work carried out by previous generations of scientists.

During his professional career he made contact and established friendships with professionals from very different backgrounds, such as Leonardo Torres Quevedo (author of the Niagara Falls ferry, still in use today), with whom he worked in his early years, or the brothers Regino and José Borobio, disciples of the architect Fernando García Mercadal, who introduced the ideas of modern rationalism to the city of Zaragoza. In later years he became President of the Higher Council of Public Works.

Another feature to stress is his keen interest in all aspects concerning the use and exploitation of water: irrigation, sanitation, etc., which led him to promote the creation of the Hydrological Confederations, an organisation from which the water resources of the river basins would be managed in an integrated manner, overcoming the provincial divisions. This model was copied on an international scale. He was also the founder of the Centro de Estudios Hidrográficos, which, throughout its existence, shared a space on what was known as the Hill of Sciences (Cerrillo de San Blas), in correlation with other scientific institutions, such as the Astrological Observatory, the Royal Botanical Garden, the Hospital de San Carlos and what is now the Prado Museum, formerly the Museum of Natural Sciences.



Work is currently underway on the development of contents, research and selection of objects and models.

Further, within the research section of the centre and in collaboration with the Geotechnical Laboratory of CEDEX, some work has been carried out to recover and enhance the collection of stone materials for public works catalogued by the naturalist, geologist and geographer Francisco Hernández-Pacheco. The collection, of great interest for the study and dissemination of public works, belongs to CEDEX's Geotechnical Laboratory, under the supervision of the Centre for Historical Studies of Public Works and Urban Planning (CEHOPU), where the Microscopy and Petrography Cabinet is kept, and at which Francisco Hernández Pacheco carried out his work as director of the Geological Service of the Transport and Soil Mechanics Laboratory, later renamed the current Geotechnical Laboratory, between the 1950s and 1970s.

The archive of stone materials catalogued by the Professor Hernández-Pacheco is kept in the cabinet, which displays the wide range of rocks used in Spain during the 20th century for public works.



A research project is also being carried out focusing on the study of renowned figures in the field of public works of the 19th and 20th centuries.

EXHIBITION THE ENLIGHTENMENT URBAN PLANNING. THE FOUNDING OF CITIES IN THE 18TH CENTURY

The period known as the Enlightenment matured in Spain during the second half of the 18th century. It was a period characterized by the coming to power of a ruling class interested in promoting the modernization of economic, political and social structures in order to structure and unite a country with enormous regional differences in terms of demographic density, orography and communications. All in all, this was a transitional stage, with a marked reformist ambition, in which significant factors were present for a historical transformation that did not become effective until much later.

In order to reform, however, it was necessary to know the reality. Hence his eagerness to gather accurate information on the ground: Ensenada's cadastre, the preparation of reports and maps, and the creation of the Royal Spanish Academy of History (1738). On Campomanes' initiative, the latter compiled a large amount of information with the aim of producing a Geographical and Historical Dictionary. Moreover, following a practice that was already fashionable in Europe, a taste for travel was cultivated among intellectuals and politicians so as to provide them with a more panoramic view of the country.

The exhibition will be based on the iconography of the period: plans, maps, manuscripts, paintings and photographs belonging to institutions such as Madrid City Council, the San Fernando Arsenal Museum (Cádiz), the Academy of Military Engineers, the Naval Museum, the General Archive of Simancas, the Army Geographical Centre, the Institute of Military History and Culture and the Museum of the City of Lisbon, among others. New models and visual elements -scenifications, interactive videos- of those cities located in territories of great strategic value will also be produced.



Researching is the mainstay that supports CEHOPU's different projects, which are materialised in exhibitions and publications.

A research project is also being carried out focusing on the study of renowned figures in the field of public works of the 19th and 20th centuries, opening up the spectrum to all the professionals involved, from engineers and architects to geologists, physicists and chemists who participated and were essential in the development of the technique and the execution of the works. In this way, the fundamental works of Spanish engineering, mainly bridges and dams, are being studied through the biographical study of their authors. The research approach, chronological and grouped by authors, makes it possible study and relate the works from the perspective of the evolution and learning process by Spanish technicians over the last two centuries.

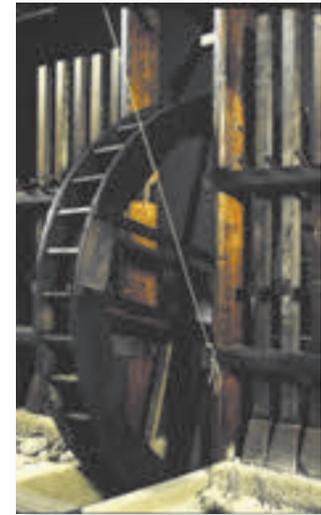
Through a selection of original writings by the protagonists, and the production of new texts of analytical and critical character, a journey throughout the personal and professional lives of each of the selected profiles is being planned in order to provide a complete vision of the scientific and constructed legacy of modern Spanish public works. These writings are accompanied by a compilation of their most significant work, prepared in the form of files that include the fundamental data of such works, as well as a selection of the graphic

CARLOS FERNÁNDEZ CASADO ARCHIVE

The archive of the engineer Carlos Fernández Casado is housed by CEHOPU, following the signing of an agreement on 27 February 2008 between CEDEX and the heirs of Carlos Fernández Casado and his company, with the commitment to facilitating the research, dissemination and conservation of his work and way of thinking.

The main content consists of files and projects of civil engineering works from the technical office that bears his name, and from his personal archives. In addition to plans, technical proposals, estimates and structural calculations, these files contain numerous photographs taken before, during and after the execution of the works. The collection is completed by other documents of various kinds (correspondence, manuscripts, photographs) of the engineer.

The documentation is organised in a main series, corresponding to files and civil works projects. Correspondence, manuscripts and graphic materials (not directly related to building projects) are collected in three separate series. The archive has an inventory of more than two hundred works and nearly two thousand photographs.



Model of an almadenetas mill. Silver industry. CMHOP. CEHOPU.

material collected in the archive. In this sense, the work undertaken by CEHOPU in previous years continues, focusing on the study of important engineering figures that has resulted in exhibitions or publications of importance, such as those of Carlos Fernández Casado, Ramón Iribarren, Rafael Guastavino or Eduardo Torroja, among others. In this case, the aim will also be to promote and disseminate the importance of CEDEX since its foundation as a pioneering and thriving centre in the field of public works. For this reason, the selection of distinguished figures is beginning with engineers and scientists who have been part of CEDEX's history throughout their careers.

The research work involves exhaustive attention to the original written sources, and drafts held in the General Administration Archive. Much of the value of the research lies in the collection of all this unpublished material, its organisation, and subsequent elaboration as the main content for scientific articles, publications, papers and exhibitions that can be derived as a result of the project's dissemination.

On the other hand, and as has been the case for the last two years, we are participating in an R+D+i action with the UNED, the Autonomous University of Madrid, the University of Barcelona, etc., financed by the Ministry of Economy, on *The Drawing of Engineers in the Modern Age: The Cities of the Mediterranean (16th-18th Centuries)*.

CEHOPU, in exercise of its powers, and as part of its activities dedicated to conserving, studying and disseminating the bibliographic



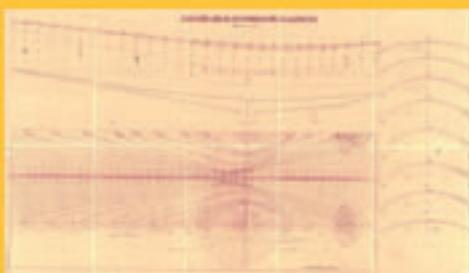
CEHOPU hosts the respective project archives of the engineers Carlos Fernández Casado and Eduardo Torroja Miret.

EDUARDO TORROJA MIRET ARCHIVE

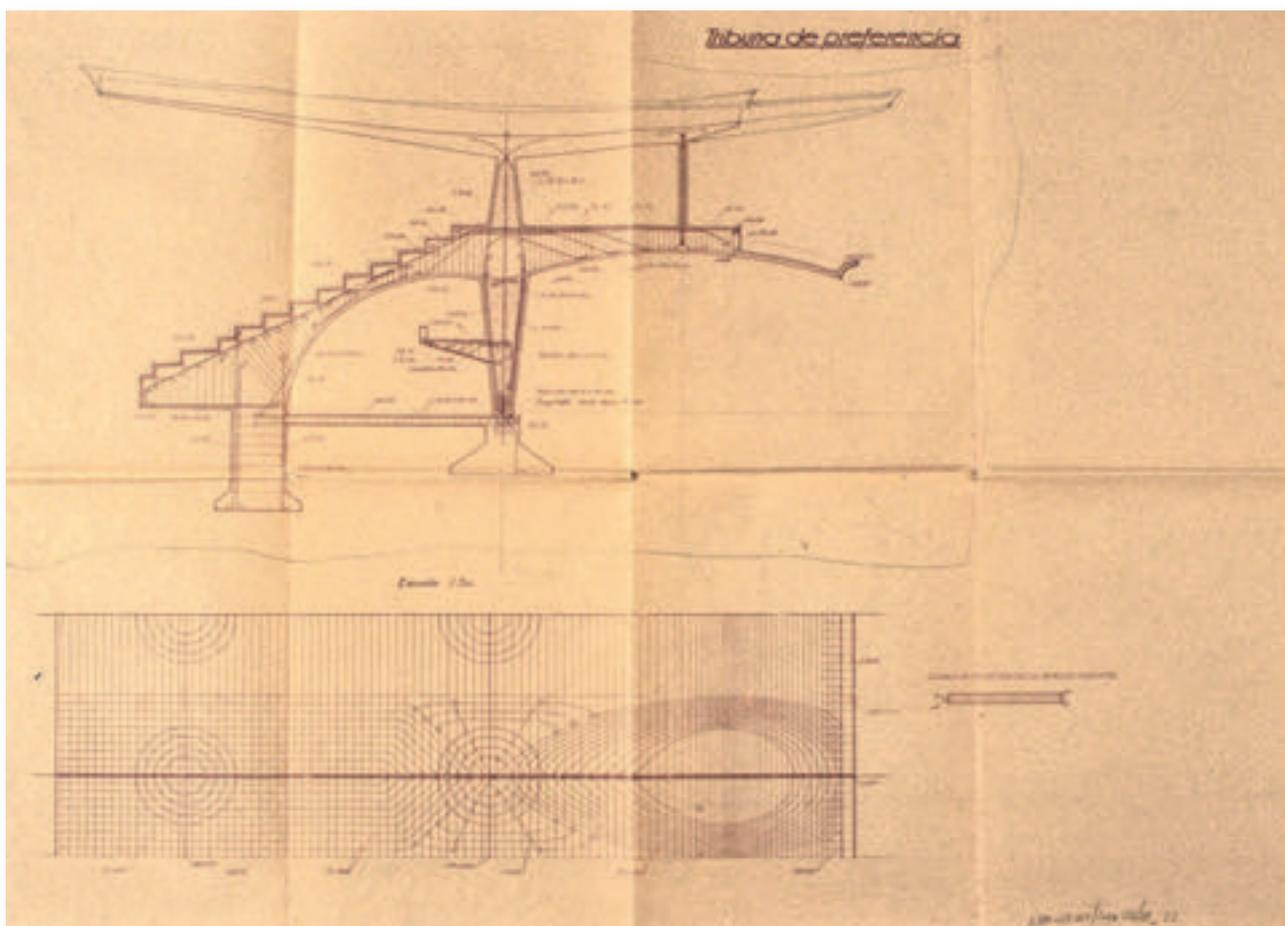
The archive of the engineer Eduardo Torroja Miret is deposited at CEHOPU. The documentary collection is mainly related to the activity of Eduardo Torroja Miret (1899-1961), one of the most important Spanish civil engineers of the 20th century, both for his professional and teaching work, and for his role as a researcher and construction theorist. His contributions in the field of reinforced concrete structures brought him worldwide recognition, being some of his most emblematic works the Recoletos Fronton, the grandstand of the Zarzuela Hippodrome and the Algeciras Market. He belonged to numerous prestigious national and international bodies related to construction and public works, and received the most prestigious awards in his field.

The Torroja archive stems from the documentary collection of the Technical Office of the civil engineer Eduardo Torroja, created in 1927, although it also includes some of his earlier works carried out at Hidrocivil, and up to 1965, including part of the work by his son, José Antonio Torroja.

The collection includes professional documentation (public works, building and town planning projects, mostly copies, with handwritten texts, some original plans and photographs), personal and family documentation (photographs, correspondence) and scientific documentation and teaching material.



Project for a new hippodrome in Madrid. 1935-05. A section of the grandstand. Eduardo Torroja Archive, ETM.



COLLECTION OF STONE MATERIALS FOR PUBLIC WORKS CATALOGUED BY FRANCISCO HERNÁNDEZ-PACHECO

From 1958 to 1972 Francisco Hernández-Pacheco was in charge of the Geological Service of the Transport and Soil Mechanics Laboratory of CEDEX, later called the Geotechnical Laboratory. At his office on Cerro de San Blas, Hernández-Pacheco undertook a study of the identification and characterisation of the different stone materials exploited across the peninsular territory, which were subsequently subjected to specific tests in order to be used in public works. He carried out a microscopic study of each of the rocks, which was accompanied by a brief summary of their characteristics, following a type of basic data sheet. Likewise, in collaboration with the regional materials services, he promoted a pioneering study of the national quarries with the aim of having statistics and precise information on the types of rocks supplied by each one of them. As a result of two decades of work, the Geotechnical Laboratory has an archive of stone materials, mostly used as aggregates, catalogued by Professor Hernández-Pacheco, which currently represents an interesting sample of the types of rock used during the 20th century in Spanish public works.



Collection of stone materials for public works catalogued
by Francisco Hernández-Pacheco

heritage of public works, holds in its documentary centre the project archive of the eminent engineer Eduardo Torroja y Miret.

The centre manages, catalogues and assists the public regarding the websites of the Torroja and Carlos Fernández Casado archives, both of which are on loan from the families of the two engineers.

Both archives have kept on digitising documents with their own resources so as to increase the contents of the website with the electronic material obtained. In this line of activity, as has been the case since the CEDEX was set up, there has been a significant volume of requests through the website from scholars and institutions asking for access to, and reproductions of, these collections. This has been a successful outcome, achieved by making this interesting collection available online to researchers from all over the world.



In collaboration with CEDEX's Geotechnical Laboratory, some work has been carried out to recover and enhance the collection of stone materials for public works catalogued by the naturalist, geologist and geographer Francisco Hernández-Pacheco. This archive of stone materials displays the wide range of rocks used in Spain during the 20th century for public works.

CEHOPU VIRTUAL MUSEUM

In order to publicise the centre's activities, an attractive website is maintained, called the Virtual Museum, which can be consulted from the CEDEX website. The museum displays more than twenty-five exhibitions held by CEHOPU since its creation in 1984. It explains the contents, the people and institutions involved, the models related to the exhibition, and the evocative images of the first inauguration and the subsequent venues where they have been mounted.

These materials are the result of CEHOPU's thirty-five years of activity in disseminating the history of public works in Spain. As a result, a collection of models has been built up, currently totalling more than 500 pieces. This collection is known as the Collection of Models of the History of Public Works.

The Virtual Museum has an integrated search engine for information on the models and contents of the exhibitions. With regard to the models, it's possible to make generic or specific searches in free text. It's also possible to search by author, exhibition, place and date. By choosing one of these, a third box is activated, which shows the way to find the selected element as it's included in the Virtual Museum.

Likewise, the search can be narrowed down by using the filter options that appear in the boxes on the right containing the subjects and by hanging the descriptors on them. In this way, as you deactivate the tabs, the search will be limited to the subjects one has clicked on.

On the other hand, once a model has been clicked on, an explanatory sheet appears, together with a photograph that can be downloaded, and a series of data on the right-hand side from which new searches can be made. One of these fields corresponds to the exhibition to which the model belongs. By clicking on it, you will find the information corresponding to that exhibition, with an explanation of its contents and the most relevant data.



CEHOPU Virtual Museum.

KNOWLEDGE TRANSFER



CEDEX's Knowledge Transfer is framed within both its Statutes and Strategic Plan, and constitutes a transversal support activity that provides support to all its centres and laboratories, as well as to the sectors related to civil engineering and the environment, through the dissemination of scientific-technical knowledge and innovation. This activity is carried out through the Training and Documentation Unit that belongs to CETA.

Its areas of work are as follows:

- Professional Training
- Publications
- Documentation and Library Network

PROFESSIONAL TRAINING

The Training Unit has continued working along the lines of previous years in order to facilitate knowledge transfer, managing its activities with efficiency and quality, and with the aim of undertaking the continuous training of CEDEX personnel, and promoting technology transfer among civil engineering and environmental professionals.

The global activity of CEDEX Training Unit has focused in 2020 mainly on staff training and the *Master's Degree in Soil Mechanics and Geotechnical Engineering*, as the rest of the regular face-to-face activities couldn't be carried out given the pandemic situation.

Courses

Master's Degree in Soil Mechanics and Geotechnical Engineering

With regard to long-term courses, the *Master's Degree in Soil Mechanics and Geotechnical Engineering* was taught as a degree of the National University of Distance Education (UNED). With 16 students, 10 from Spain and the rest from Latin American countries (Argentina, Perú, Costa Rica and Guatemala), it's entailed 560 teaching hours, including the preparation of a master's thesis, to form part of the training offered by this university, 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 taught by the Geotechnical Laboratory of CEDEX without interruption since the 1980s. In 2000 it acquired the category of Master's Degree, and from 2009, first with the Universidad Politécnica de Madrid (UPM) and currently with the UNED, it enjoys university status as a degree.



Leaflet presenting the *Master's Degree in Soil Mechanics and Geotechnical Engineering 2020*.

Selective Courses for Access to the Specialised Bodies of the Administration and Scales of Optional Technicians of Autonomous Bodies of the Ministries for Transports, Mobility and Urban Agenda (MITMA), and Ecological Transition and the Demographic Challenge (MITERD)

In the premises managed through the CEDEX Training Program, in collaboration with the Subdirector General of Human Resources of the General Inspection of MITMA, selective courses have been organised for access to the bodies of Topographical Technical Engineers, and Public Works Technical Engineers, respectively. The rest of the selective courses to be held at CEDEX facilities had to be cancelled.

Other organisations have used CEDEX facilities to organise tests for different specialities, such as the tests for Knowledge of the Port Pilotage Service of the Directorate General of the Merchant Navy. Besides, and among others, examinations for the renewal of Dangerous Goods Transport Safety Adviser certificates took place.

Other Courses and Conferences

Amid the different activities of the Training Unit, it's noteworthy the organisation of 18 events, including meetings, platforms, conferences, exams and committees, at CEDEX facilities, which have been chosen by numerous institutions, both public and private, as venues, attracting a good deal of visitors.

Moreover, the *5th Initial Training Program for Road Safety Auditors* was managed in a common module and two specific modules.

Internal Training

With regard to the internal training of CEDEX staff in application of the *2020 Continuous Training Plan*, new training activities have been developed as a result of the needs detected by the agency's management, trade union organisations, commissions, and public employees. In this kind of courses, it's worth highlighting the adaptation to new training technologies, with the bolstering of training activities in streaming due to the impossibility of delivering on the face-to-face way. In 2020,

| CEDEX INTERNAL TRAINING COURSES | | | |
|--|-----------|------------|---------------|
| COURSE TYPE | COURSES | ATTENDEES | LECTIVE HOURS |
| Information and communication technologies | 13 | 177 | 236 |
| Foreign languages | 10 | 83 | 160 |
| Specific and environmental posts | 12 | 119 | 148 |
| Occupational health | 10 | 306 | 142 |
| TOTAL | 45 | 685 | 686 |

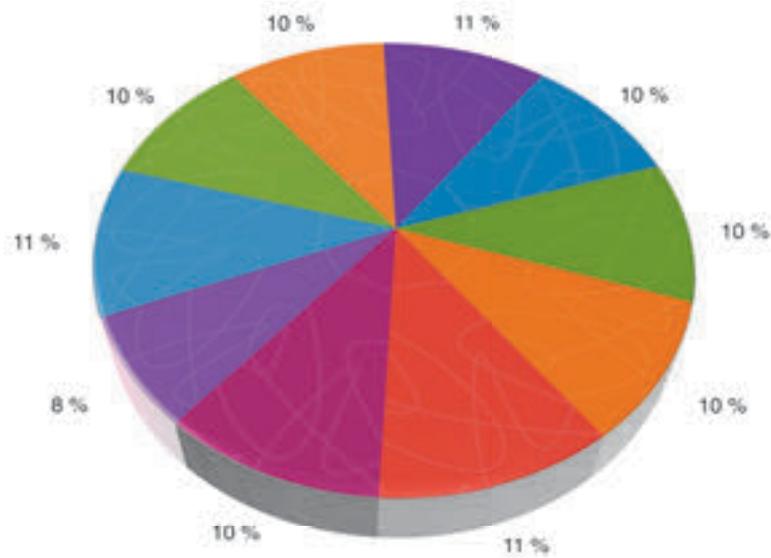
and due to the pandemic, staff training went online mode. The courses carried out this way have been gaining acceptance, and have ended up yielding very positive results, thereby buttressing digital learning and connectivity. The GoToMeeting communication platform has been the mainstay for the online learning courses. Plus, a Moodle tool has been developed with the support of the CEH, facilitating the management of the courses in a more efficient way. The courses have taken place in various modes: 1 on-site, 10 online, and 34 in streaming.

Thus, the aforementioned plan is deemed as a key factor to ensure the highest quality of CEDEX's services, and not only concerning bureaucratic aspects, but especially in the various specialised technical activities in which a research and experimentation public agency, such as CEDEX, is strongly committed to being at the forefront of innovation. All this without leaving aside the right of public employees to training, and professional and personal development.

Bearing this in mind, 45 courses have been held, with a total of 685 hours and 268 students (98 women and 170 men).



Professional online meetings.

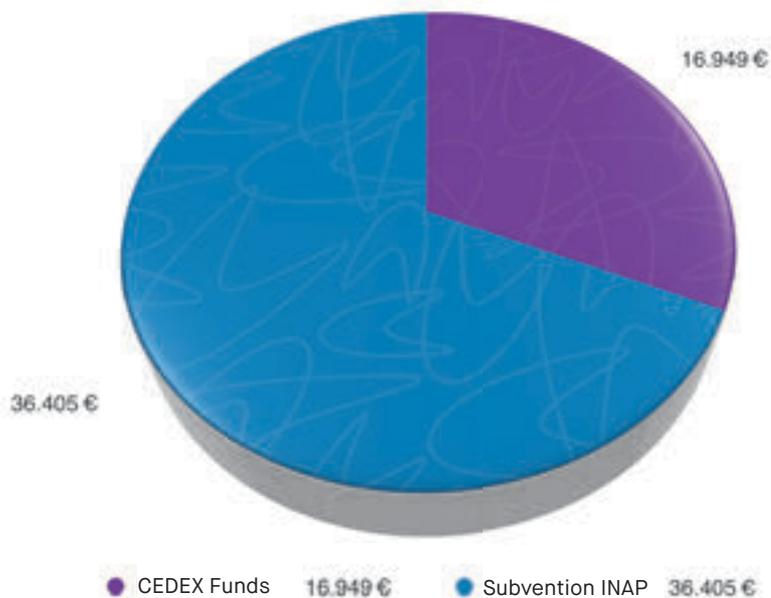


- The information I received about the courses was right and delivered on time
- The organization of the courses was correct
- The access to the contents through the Moodle platform has been easy and convenient
- The access to the sessions with the GoToMeeting tool has enabled good communication
- Technical problems have been sorted out
- Technical means provided by CEDEX have been adequate
- I prefer online rather than face-to-face training
- I found the course interesting
- The course contents have met my training expectations
- The level of course contents is adequate

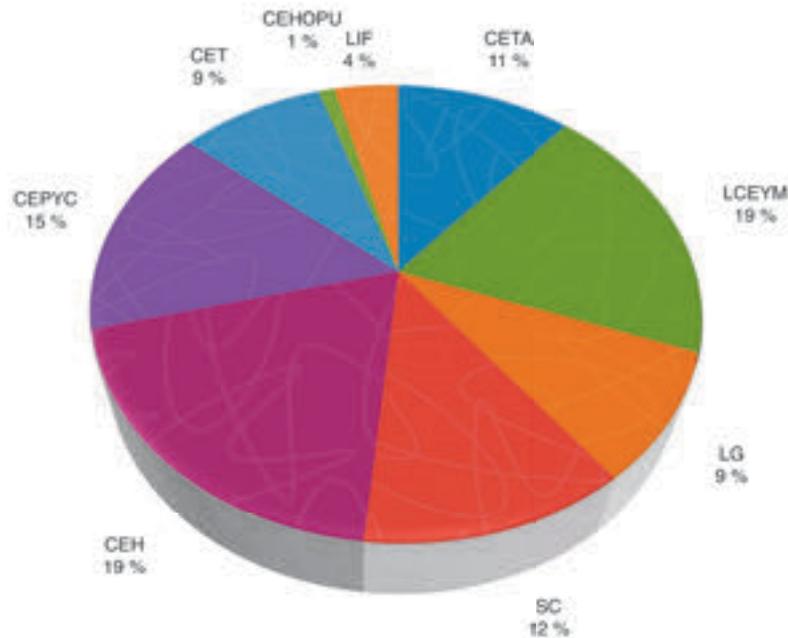
The overall evaluation of the courses by the attendees has been very positive.

The continuous training courses were partly subsidised by INAP and, also, by CEDEX own resources.

The courses were distributed by participation among all CEDEX's centres and laboratories.



Participation by centre/laboratory in the training was distributed as follows



International Activity

The Training and Documentation Unit was commissioned by the CEDEX management to re-establish the institutional relations with the French entities L'Office International de L'Eau and CEREMA.

CEDEX has been a member of the Board of Directors of L'Office International de L'Eau for many years, having worked together on European projects such as SEMIDE.

CEREMA is the French public institution of reference for developing and capitalising on public expertise in development, territorial cohesion and ecological and energy transition. It offers unique expertise in the fields of mobility, transport infrastructures, territorial and construction engineering, environment and risk prevention, road and maritime safety and has the capacity to integrate these different competences in the construction of territorial projects. As a multidisciplinary centre of scientific and technical resources and expertise, it assists in the development, implementation and evaluation of public policies, both at national and local level. It provides direct support to

government services, communities and companies (pre-AMO, AMO, specific operational missions, etc.). It develops, experiments and disseminates innovative solutions.

In view of the parallelism of the scope of competence of both entities in their respective countries, as well as the added value that mutual knowledge and collaboration between them would bring, CEDEX and CEREMA have considered, in their mutual interest, formalising a *General Protocol of Action* in order to define a general framework of collaboration, the areas of which are detailed below:

- Water Domain: Ports, Coasts (Coastal) and Marine Environment, and Inland Waters.
- Roads Domain: Infrastructures and Pavements.
- Transport and Mobility Domain.
- Environment, Climate Change and Sustainable Development Domain.



The sort of collaboration actions may include:

- Technical assistance
- Research, development and innovation, and participation in projects financed by the European Union
- Knowledge transfer and support for the translation of technical guides in Spanish / French

PUBLICATIONS

CEDEX, in its capacity as a publishing unit of the Ministry for Transports, Mobility and Urban Agenda, and within the *General Publications Plan of the General State Administration (AGE)*, has continued to promote knowledge transfer through the agency's technical publications and the *Civil Engineering* journal.

In 2020, it's continued to disseminate technical and innovation topics in the fields of public works, civil engineering, environment, and sustainable mobility. This editorial program serves as an instrument to publicize the activities carried out in the AGE, generating a benefit for citizens and social agents.

Thanks to the *CEDEX 2020 Publishing Program* 23 publications have been published in both paper and electronic format:

- *History of the Spirit and Culture of Water: Anthropology and Ethnography. Volume II*
- *Impact of Climate Change on Water Resources and Droughts in Spain. Update After the 5th IPCC Assessment Report (M-142)*
- *José M^a Martín Mendiluce. Memories and Anthology*
- *Carlos de Grunenbergh. A German Engineer in the Service of Charles II in Sicily*
- *Norm NLT-383/20. Evaluation of Strength, Toughness and Fracture Energy of Bituminous Mixtures by Means of the FENIX Test*
- *2017-2018 Digital Gauging Yearbook*
- *Digital Catalogue of CEDEX Publications*
- *CEDEX Training Course Handouts*
- *CEDEX: Technical and Scientific Activities, 2019*
- *CEDEX: Technical and Scientific Activities, 2019*
- *CEDEX Strategic Plan for 2020-2022*



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

INGENIERÍA CIVIL JOURNAL

In 2020, three issues of the *Ingeniería Civil* journal (195, 196 and 197) have been published, instead of the regular four ones brought out annually, owing to the anomalous situation produced by the pandemic.

The three issues have been published both on paper and digitally, being freely accessible, as well as the historical archives of the journal, in electronic format (PDF and XML/HTML), through the official website CEDEX (<http://cedex.es>).

Further, all official CEDEX publications are also available in the new *Catalogue of Publications*, accessible at <https://catalogo.cedex.es>

DOCUMENTATION AND LIBRARY NETWORK

The Library Network, coordinated by CEDEX's Central Library, has continued with its objective of supporting the research and technical assistance processes of the organization, making available to its technicians the documentation required for the development of

the work carried out at the different centers and laboratories of the CEDEX.

As in previous years, there's been a single budget for the purchase of bibliographic resources, managed by the Central Library, which has made it possible to satisfy all requests for books and other documentary resources without any restrictions.

The collective catalogue of the library network has increased by 400 records, reaching 131,201 titles and 165,739 volumes. The catalogue includes monographic titles, journals, maps, electronic resources, and more than 9,582 technical reports prepared by CEDEX.

Access to the catalogue is public, and available for consultation on Internet at <http://vopac.cedex.es/opac>.

As in recent years, no subscriptions or renewals of titles have been made. We have only received those journals obtained by donation, exchange with our journal *Ingeniería Civil*, or those published by organizations or

associations to which CEDEX belongs as a member.

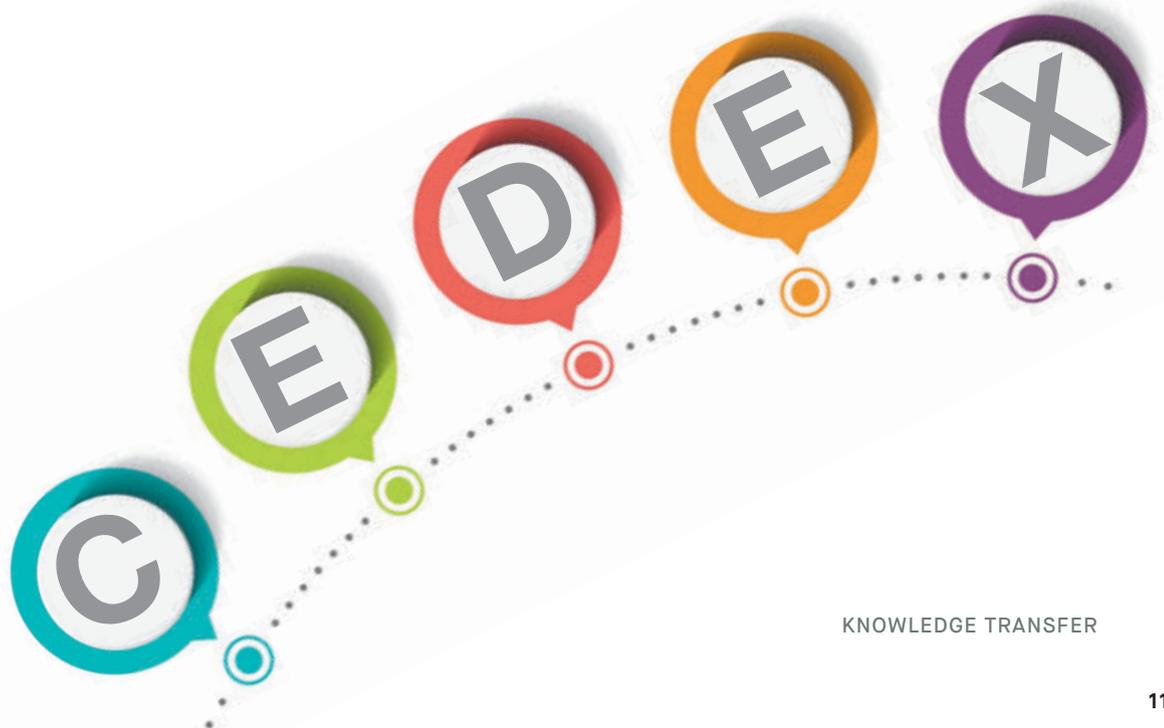
As in the preceding years, this lack of subscriptions has been made up for by the online "Article Choice" subscription for downloading articles from Elsevier's ScienceDirect database, which allows access to any article from the more than 3,800 titles in this publisher's journal collection. To obtain articles from other publishers, interlibrary loan has been used.

The subscription to the WOS (*Web of Science*) databases has also been renewed through the FECYT. By accessing these databases, technicians and researchers have been able to know the bibliography published in their respective areas of interest, the impact obtained by the articles they have published in international journals and the citations of these articles, as well as to search for interrelated

articles and receive content alerts for their areas of interest and research.

When it comes to customer services, in 2020, owing to the Covid-19, face-to-face attention was concentrated on the first two months of the year, after which attention to the public was provided by e-mail. Soon after the lockdown, a researcher was attended to in person for a doctoral thesis in the Geotechnical Library. Also, the requests which, due to their size, could be sent by e-mail were digitalized.

Coordination has been established with the CEHOPU in order to service on-site research of documents from the Torroja and Fernández Casado archives; on-site research which, also due to Covid-19, has been significantly lower than the previous year. At the Central Library Reading Room four people were assisted.







RELEVANT PROJECTS

REPARA 2.0 PROJECT – INSTALLATION AND OPERATION OF A ROAD VEHICLE WEIGH-IN-MOTION (WIM) SYSTEM



Contact: Jesus.Leal@cedex.es

Within the framework of the REPARA 2.0 Project “Development of new techniques and information systems for the sustainable rehabilitation of road pavements” there is a work topic that is based on the assumption that the instrumentation of pavements can be a powerful tool for the investigation of pavement behaviour. That is why a new advanced instrumentation scheme for the dynamic monitoring of pavement condition is being defined and deployed by using Big Data techniques, which comprises the use of sensors embedded in the pavement, as well as going forward in the use of wireless communications, though the Internet, to transmit the data from those sensors.

In accordance with the proposed instrumentation scheme, a vehicle weigh-in-motion (WIM) system has been installed on the A-1 motorway near El Molar (Madrid), in the right lane of the carriageway towards Madrid, whose objective is to provide a comprehensive and permanently updated information on the gross weights and axle loads of the vehicles travelling on the motorway, which are essential input data in the prediction models of the deterioration process of a road pavement.

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



Figure 1. Execution of the pavement cut with a diamond blade saw to excavate the grooves where the sensors are inserted. Appearance of the piezopolymer sensor in the groove. Cabinet that houses the electronic equipment that governs the operation of the WIM system.



Figure 2. Appearance of the weight sensors and the induction loop installed on the road. Technician of the installation company checking the electronic equipment housed in an outdoor cabinet, next to the solar panel for electricity supply.



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

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 supply for the operation of the system.

This WIM system is designed to obtain a detailed and in-depth knowledge of the weights and loads of the heavy vehicles travelling on the road network, in order 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, that can be used for their more accurate structural design.

CLARITY PROJECT



Contact: laura.parra@cedex.es

Tools like the one developed by CLARITY Project will help to fulfill this challenge, with the objective of making our cities and transport infrastructures more sustainable and more resilient to climate change.



The CLARITY Project, funded by the EU under the umbrella of the Horizon 2020 programme, has developed a climate service (CSIS) that hosts an online tool to assess urban and transport infrastructures risk to climate change, providing the most representative climate variable projections that represent the most likely hazards that might endure both our cities and our transport systems.

EU is committed to making sure that climate data is used in the form of indices that are included in decision making processes (energy, agriculture, buildings, transport, etc.).

The Project, which has been going on for 39 months, finally ended in august 2020. During this period, a wide amount of climatic and geographical data have been collected. Future projection of the relevant climatic variables have also been calculated and impact and vulnerability assessment methodologies have been tuned.

The climate service has been tested in three European cities: Stockholm, Naples and Linz, taking into account their particularities. In Spain, the climate service has been implemented in a road infrastructure: a four lane highway section 73 km long, running from Guadalajara city (pk. 62) to Alcolea del Pinar (pk. 135).

For transport infrastructures, the climate service provides the following results:

- Identify the main climate impacts that might occur, by calculating the projections of the climatic indexes relevant to road design, construction and operation
- Assess the risks of climate variability.
- Proposal of adaptation measures.

The companies that have contributed to the Spanish pilot case are: CEDEX, Acciona Ingeniería, AEMET, ATOS and Meteogrid.

Climate variability is an element that has to be taken into account into infrastructure design, building and operation.



PROJECT DURATION: 39 months
1st June 2017 to 31st August 2020
17 companies and centers involved
www.clarity-h2020.eu
twitter @clarity_h2020



In the middle term, it is expected that CLARITY tool is hosted at CEDEX and therefore will be available for performing assessments and implementing strategies for climate change mitigation and adaptation.

The Project has successfully ended. A good number of workshops and webinars have been done. This has allowed to disseminate the Project results and showcase the strengths of CLARITY tool both in road infrastructures (A2 pilot case) and railway infrastructures.

TESTING OF TWO SECTIONS OF BITUMINOUS MIXTURES MADE WITH RUBBER POWDER ON FULL-SCALE ACCELERATED PAVEMENT TEST TRACK IN CET



Contact: Rafael.RodriguezG@cedex.es

The test carried out consisted of analyzing the evolution and comparing the surface and structural characteristics of two bituminous mixtures part of the surface layer and subjected to a known heavy traffic, by means of the use of auscultation and instrumentation equipment. The difference between the two mixtures lies in the way the rubber powder is incorporated.

To carry out the test, the two bituminous mixture layers have been placed on the Accelerated Pavement Test Track and two heavy vehicles with a standardized semi-axis of 6.5 tons were used to apply the loads (50,000 cycles).

For the pavement instrumentation, before placing the surface layer to the spreading of the tread layer, sensors were sited to measure horizontal strains (longitudinal and transverse) at the bottom of the bituminous pavement, as well as temperature sensors inside. These measurements have been recorded every 1,000 cycles throughout the trial.

The pavement bearing capacity evaluation was carried out by measuring the deflections. The surface characteristics evolution was studied too by measuring their transverse and longitudinal regularity, as well as their micro and macro texture.



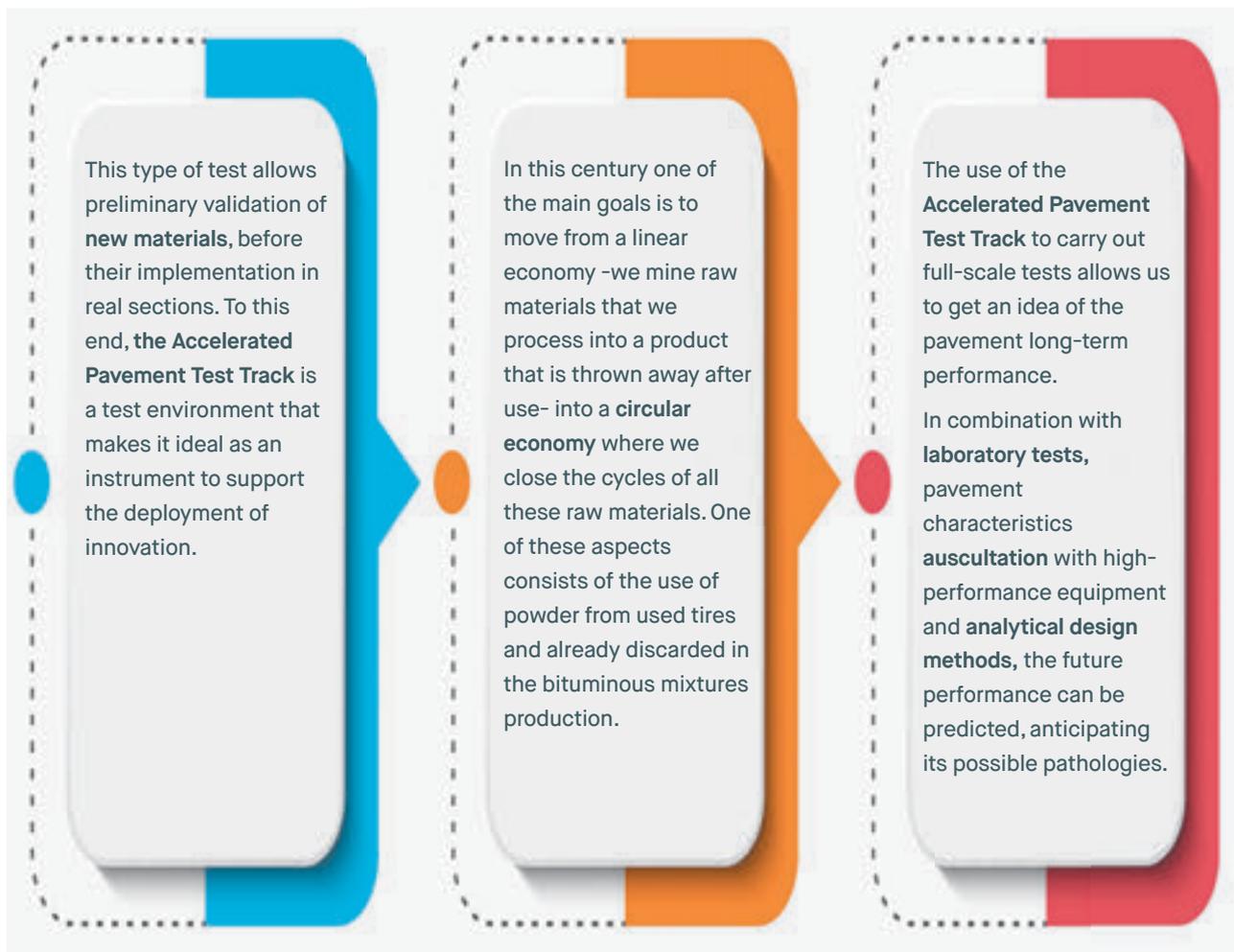
Instrumentation



Placing bituminous mixture



Heavy vehicle



Additionally, during the spreading, samples of the two mixtures were collected for their characterization through laboratory tests.

Regarding the way of incorporation of rubber powder for the bituminous mixtures production, currently the dry or wet process is used, however, in this study a third procedure has been incorporated, which consists of the incorporation of RAR-X, an additive that contains 60% rubber powder, to which the temperature is raised through an industrial process and bitumen and other components are added, in a stirring treatment until it is stabilized. The rubber is mixed with the bitumen until it reaches the maximum viscosity, at which point the process is stopped. This pre-treated product is incorporated into the filler silo and the production of the asphalt mix is completed by conventional means. This RAR-X additive aims to provide asphalt mixtures production with the ease of use of the dry process and the quality resulting from the wet process.

The test results reveal a similar performance in both samples, both at the laboratory level and in instrumentation and auscultation measurements.

HYDROMORPHOLOGICAL STUDIES IN THE EBRO DELTA. CHARACTERIZATION OF THE SEDIMENTS IN THE MEQUINENZA AND RIBARROJA RESERVOIRS AND IN THE LOWER COURSE OF THE EBRO RIVER

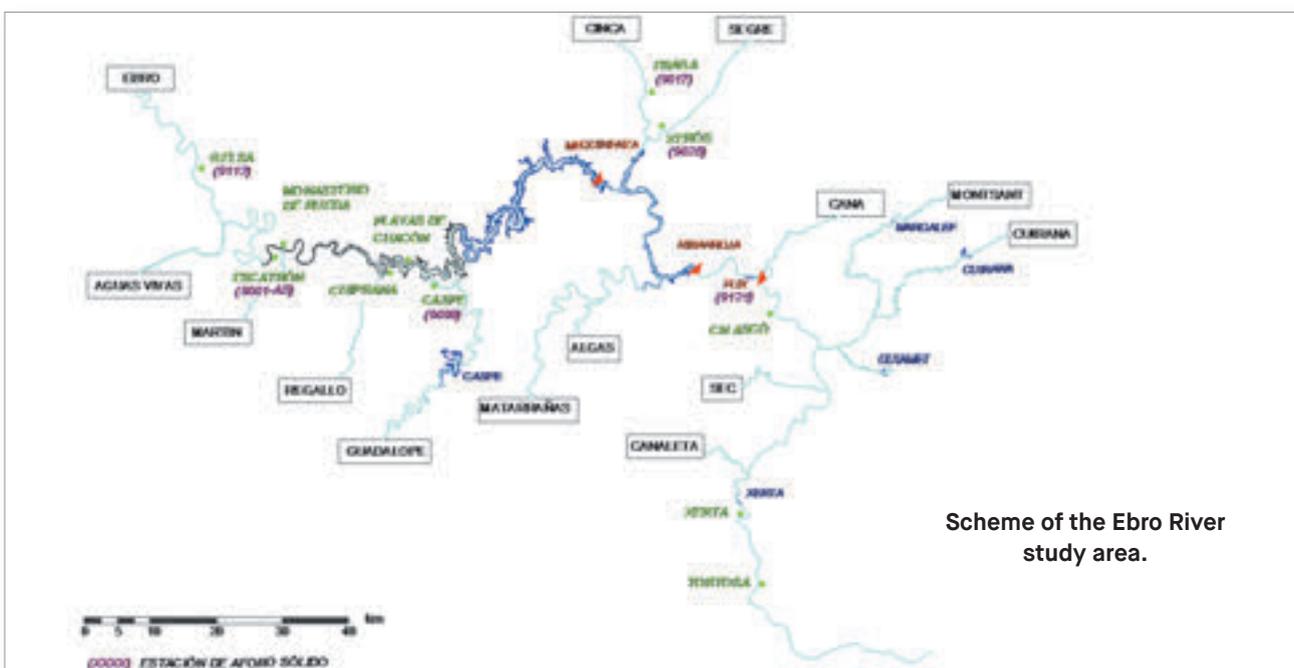


Contact: david.lopez@cedex.es

The Ebro Delta is one of the most important ecosystems in Spain. During the last century, its morphology has been altered by the construction of various regulatory infrastructures and the consequent reduction of solid contribution in the lower course of the Ebro River. During 2020 the Centre for Hydrographic Studies of CEDEX (in collaboration with the Centre for Studies on Ports and Coasts) has carried out several studies aimed at characterizing the sediments in the Mequinenza and Ribarroja reservoirs, as well as in the lower course of the Ebro River.

The characterization of the sedimentary transit in the lower reaches of the Ebro River and at the entrances to the Mequinenza and Ribarroja reservoirs is a fundamental task for the establishment of any measure aimed at improving the Ebro Delta. With this objective, in recent years A large number of technical studies have been carried out, fundamentally promoted by the Ebro River Basin Authority and by the General Water Directorate.

The data accumulated in all these studies have allowed CEDEX to carry out new analyses with different methodologies (extrapolating the trend of the annual sedimentation rates obtained



Scheme of the Ebro River study area.



Panoramic view of the Ebro Delta.

previously and by means of a correlation of the hydrological regime) as a consequence of which the volume of sediments accumulated in the Mequinenza and Ribarroja reservoirs in 2020 it has been estimated, respectively, in ranges between 242 hm³ and 244.9 hm³ and between 15 and 19.3 hm³ (on initial capacities of 1,500 and 210 hm³).

Another important analysis carried out during the last year has been the characterization of the accumulated sediments in the tail section of the Mequinenza reservoir, estimating that in the 42 km of tail of the reservoir there are currently almost 100 hm³ accumulated; In addition, of the 40 hm³ of sediment that is estimated to exist between PK 72 to 90, 20 hm³ would be sand and 5 hm³ of gravel.

On the other hand, CEDEX studies in relation to sediment transit in the lower reaches of the Ebro have made it possible to estimate that currently (2020) the transport rate of suspended sediments downstream of the Mequinenza, Ribarroja and Flix reservoir complex is of 0.37 Mt / year (during the first years after the dams were put into operation it was 0.83 Mt / year). Likewise, it is estimated that if the dams did not exist, the rate would currently be 5.16 Mt/year. To these values should be added the contributions of the basins of the lower section. All these works have been part of the contents of the Plan for the protection of the Ebro Delta, which was presented by the Secretary

of State for the Environment to the social agents of the area on November 18th, 2020.

As a result of all these works, the need to carry out a series of numerical studies of fluvial dynamics in the lower reaches of the Ebro River has been confirmed, which allow us to rigorously characterize the sedimentary transit towards the Ebro Delta. These studies will be carried out during the year 2021 and for this, the General Water Directorate is carrying out rigorous topographic and bathymetric studies in the Mequinenza, Ribarroja, Ciurana, Margalef and Guiamets reservoirs, as well as a characterization of the channels and sediments of the Ciurana, Montsant, Riera l'Ull del Asma, and the lower course of the Ebro River, so that there is updated information on the geometry of the channel with sufficient precision to be able to carry out two-dimensional numerical simulations of this stretch of river.

- The lower course of the Ebro River has suffered a very significant reduction in sedimentary traffic during the last century, associated with the construction of the Mequinenza and Ribarroja dams.

- CEDEX has carried out a series of studies in 2020 to update the characterization of the sediments in these reservoirs and in the lower reaches of the Ebro River.

INTEGRATED WATERSHED MANAGEMENT MODEL



Contact: luis.m.barranco@cedex.es

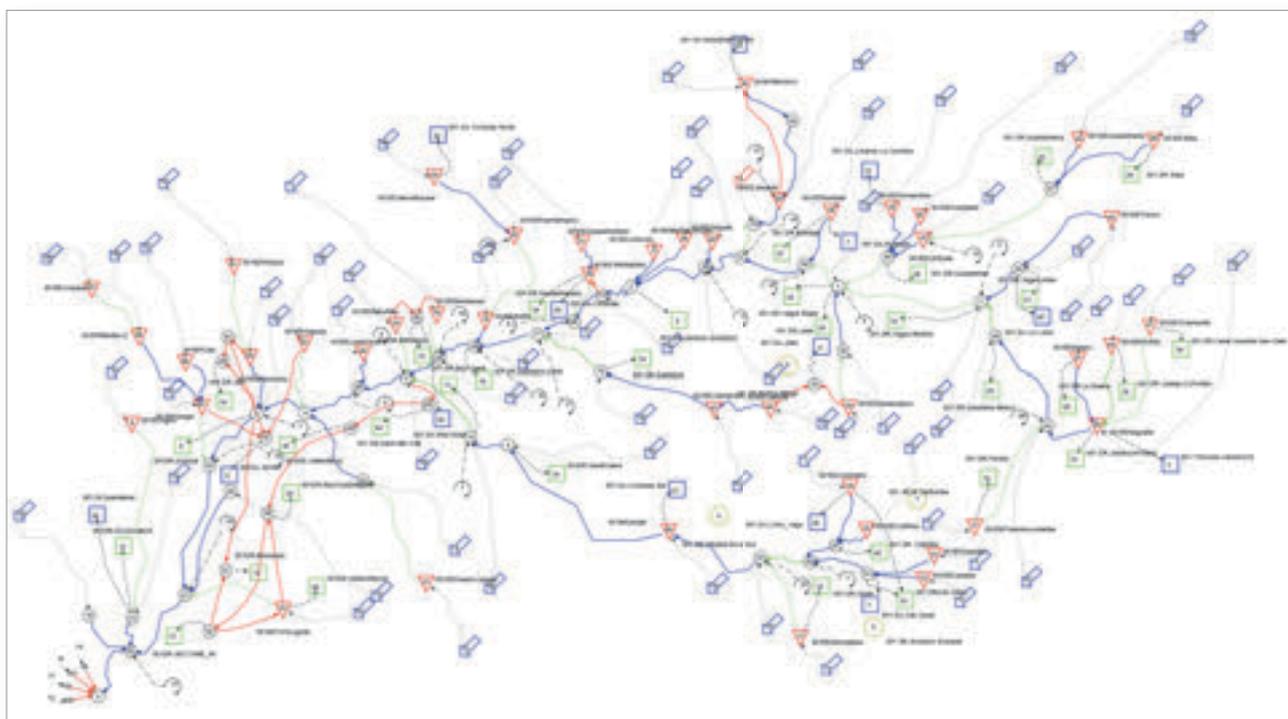
The Centre for Hydrographic Studies has updated the integrated model for the analysis of the water resources systems of the river basin authorities on a national scale, based on the information from the river basin management plans.

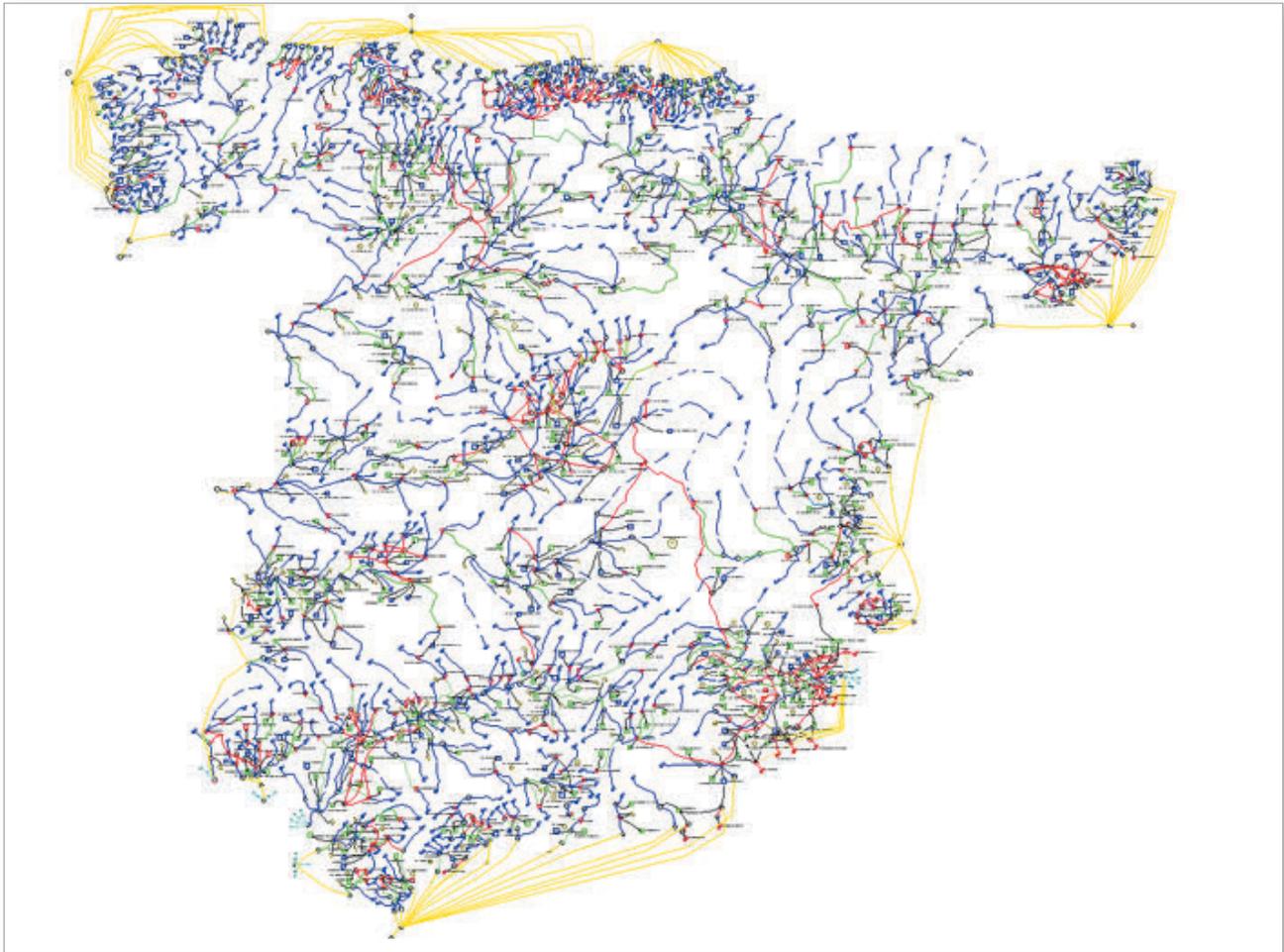
This work consists of the elaboration and validation of the national simulation model with the data from the current hydrological plans of the 2nd hydrological planning cycle (2015 - 2021).

For this elaboration, the OPTIGES optimization model was used, a tool included in the AQUATOOL+ software and developed by the Polytechnic University of Valencia. Within AQUATOOL+ there is also the SIMGES model, used for complex simulation of basins.

Thus, while the river basin authorities carry out their detailed planning models with the SIMGES simulation model, the national model supposes a more simplified representation, but precise enough to incorporate the most important

Scheme of the simplified model of the Guadalquivir River Basin Authority.





Scheme of the simplified model of the peninsular water resources system.

elements that reproduce the behaviour of each river basin district in a single national model. This simplification, in general, is based on the grouping of elements into others of greater importance (demands, contributions), or on the consideration of those based on a certain capacity estimated to be important or representative (reservoirs, pipelines).

In the framework of the aforementioned update, different works have been carried out, among which those mentioned below stand out:

- Updating of the national model according to the information of the current river basin management plans, in particular, ecological flows, contributions of natural resources and water demands.
- Calibration of the national model with respect to the models of the river basin authorities.

- Simulation of the national model for each planning scenario and analysis of the available resource.
- Simulation of different climate change hypotheses according to the report prepared by the Centre for Hydrographic Studies on the evaluation of the impacts of climate change on water resources.

- Optimization of exploitation systems to balance the available water resource.
- Usefulness for national hydrological planning, jointly analysing different river basin districts.
- Analysis of different alternatives, future demand and/or resource scenarios, climate change effect.

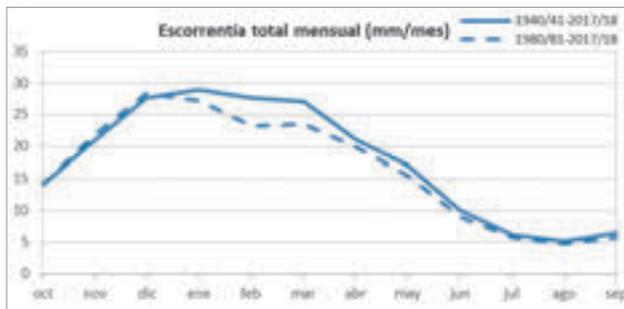
INVENTORY OF WATER RESOURCES IN SPAIN



Contact: mirta.dimas@cedex.es

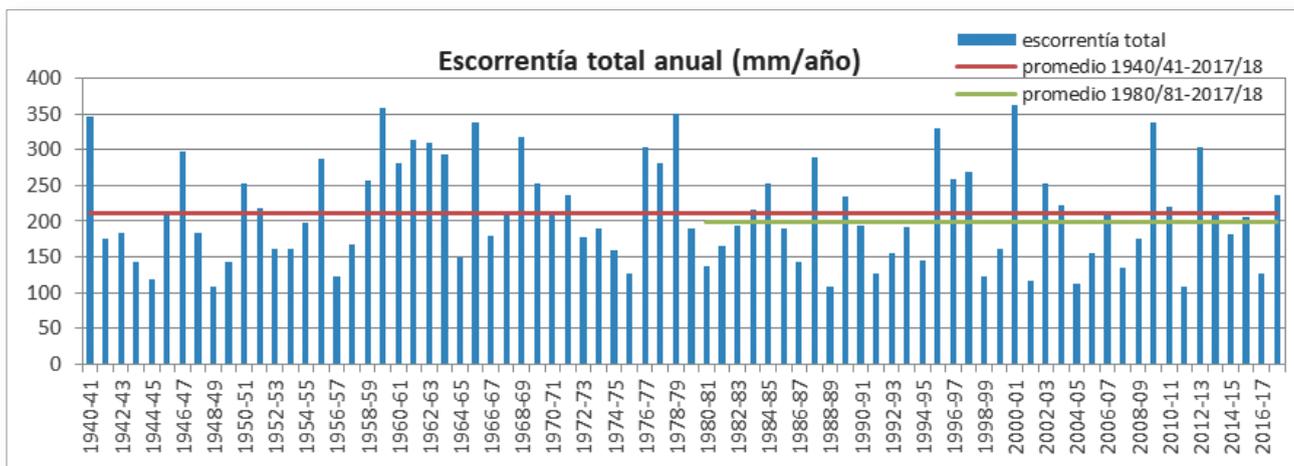
The Centre for Hydrographic Studies has concluded the preparation of the inventory of water resources in Spain in a natural regime, the results of which serve as the basis for the preparation of the river basin management plans of the third planning cycle (2021/2027).

The Centre for Hydrographic Studies has among its main tasks the improvement of knowledge of natural resources on a national scale, as is the case of the preparation of the inventory of water resources in Spain in a natural regime. During 2020, this work covering the period 1940/41 to 2017/18 was completed and sent to the General Water Directorate for distribution among river basin authorities for use in the river basin management plans of the third planning cycle.

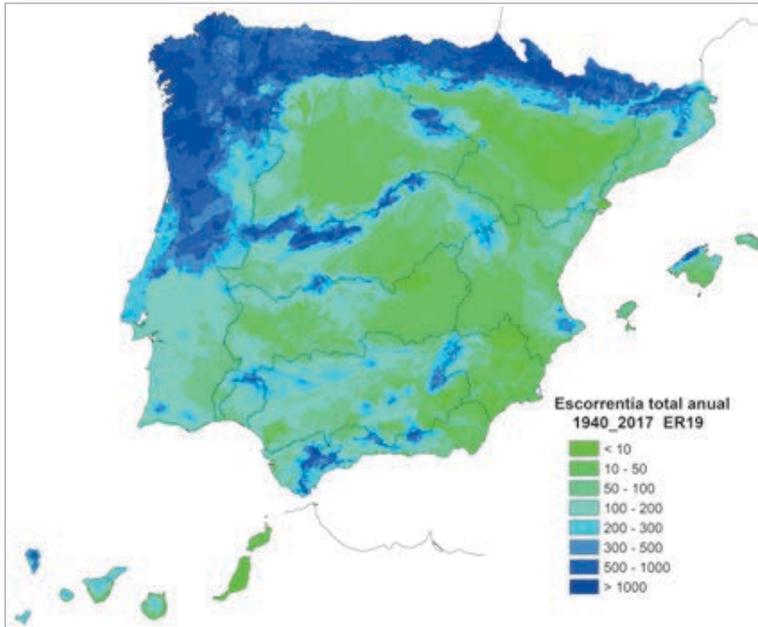


Series of monthly averages of total runoff in Spain, 1940/41 - 2017/18 and 1980/81 - 2017/18.

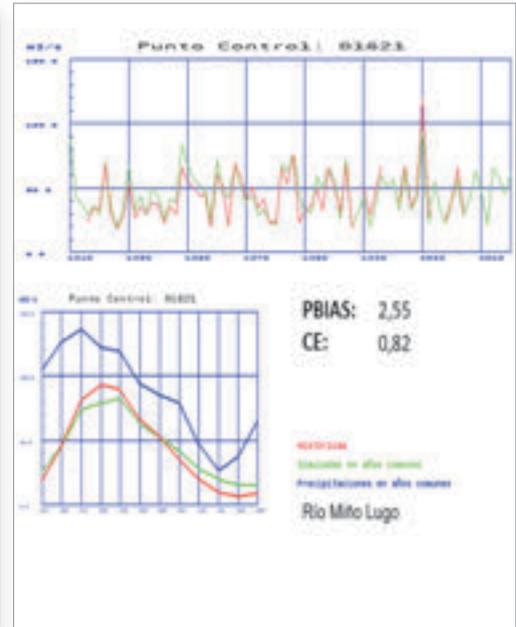
This work consists of estimating the water resources of Spain in a natural regime through the simulation of the hydrological cycle with a homogeneous and contrasted methodology in the whole of Spain, and is a continuation of other similar works carried out previously for Water in Spain, the National Hydrological Plan and the inventory of natural water resources of the hydrological plans of the river basin districts of the first cycle.



Total annual runoff series in Spain.



Spatial distribution of total annual runoff (mm), 1940/41 - 2017/18.



Contrast of the annual and average monthly flows in the Miño River in Lugo.

For its elaboration, the simulation model precipitation-contribution SIMPA developed at the Centre for Hydrographic Studies has been used. It is a conceptual and quasi-distributed model that simulates the process of transformation of precipitation into runoff, contemplating the dynamics of water storage in soils and aquifers. This model simulates hydrological processes on a monthly scale, in a natural regime and at any point in the hydrographic network.

This study undertakes a series of improvements with respect to previous versions, such as the analysis of the quality of the phoronomic data series, updating and review of the quality of the climatological series and the interpolation process, and the modification of the calculation software of the hydrological model for the improvement of snow treatment.

The work has followed the following sequential methodological stages: treatment of the atmospheric variables to obtain the monthly maps of precipitation and potential evapotranspiration, hydrological simulation and contrast of the simulated flows with respect to those observed for the calibration of the model parameters. The results have consisted of a set

of monthly, annual and average maps of the long series (1940/41 - 2017/18) and short series (1980/81 - 2017/18) of the different hydrological variables: temperature, precipitation, potential evapotranspiration, actual evapotranspiration, soil moisture, infiltration, surface runoff, underground runoff, total runoff, and accumulated inputs along the drainage network.

During the development of the work, we have had the collaboration of the Hydrological Planning Offices of the river basin authorities, the Geological and Mining Institute of Spain and with the information provided by the State Meteorological Agency.

- **Fundamental information for the revision of the river basin management plans of the river basin districts.**
- **Simulation of the hydrological cycle with a homogeneous and contrasted methodology throughout the territory of Spain.**
- **Employment of SIMPA precipitation-contribution model developed at the Centre for Hydrographic Studies.**

APPLIED RESEARCH ON PHOTOINTERPRETATION FOR THE CHARACTERIZATION OF EROSION PROCESSES IN BASINS AND RIVER BEDS



Contact: juan.j.rebollo@cedex.es

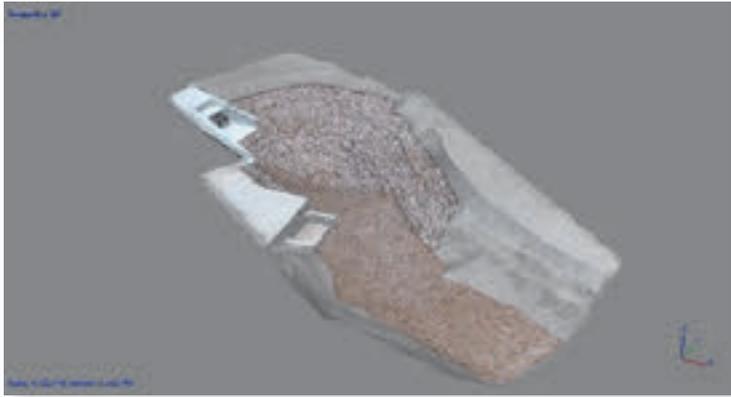
In recent years, with new advances in the field of drones and photointerpretation, various techniques have been developed to characterize, accurately and quickly, the erosions generated in stilling basins and sections of river beds during the experimental phase in physical modelling. In addition to taking zenith photographs, this methodology requires a set of additional software to generate and represent the topography, allowing the comparison and measurement of the eroded material. The Hydraulics Laboratory of the Centre for Hydrographic Studies is currently working on the implementation of these techniques in the studies it develops.

The characterization of the erosions generated during the experimentation in physical models has been, in general, one of the main objectives of the studies that have been developed in the Hydraulics Laboratory, both in the dimensioning of stilling basins of hydraulic structures and in the evolution of erodible river beds in reduced-scale physical models. The methodology used has evolved based on advances in instrumentation and measurement equipment, which were generally expensive and required a lot of time for data collection and subsequent processing.

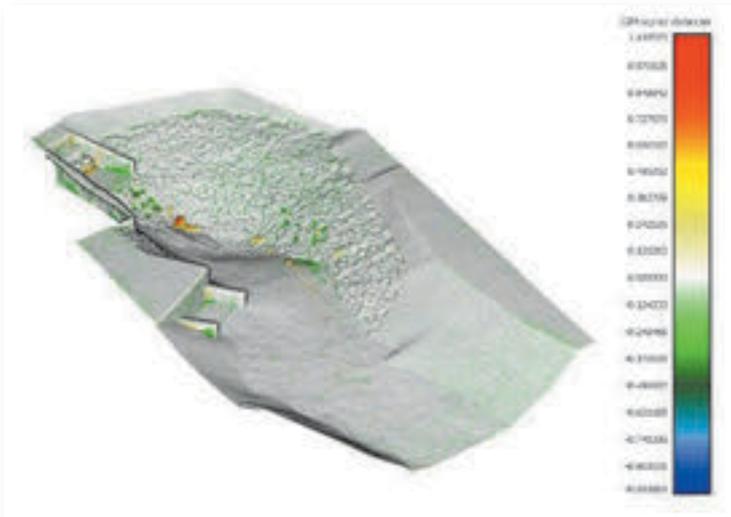
Currently, with technological advances and the expansion of drones, taking zenith photographs is fast, cheap and easy, allowing flights to be carried out immediately after each test in physical models with erodible bed. With these data, and together with additional software that allows the images to be restored with satisfactory precision, the representation of



Operation of drone equipment during physical modelling tests.



Restitution of the stilling basin of the bottom outlets of the Zufre dam physical model.



Evolution of erosion in the stilling basin of the bottom outlets of the Zufre dam.

erosion phenomena in this type of study has become a relatively simple task. The main phases of the lifting works can be summarized as follows:

- Location of different control points in the model with known coordinates that serve as a reference in the restitution phase.
- Taking zenith photographs of the eroded area with a drone, where sweeps with sufficient overlap (40%) are made in all quadrants of each image.
- Land survey using software. In this case, the METHASHAPE AGISOFT program has been used, which allows creating 3D models of complex shapes and digital elevation models of the terrain, as well as georeferencing them.
- Finally, an additional program has also been used to compare the results obtained with the initial situation (CLOUDCOMPARE),

which allows 3D data to be processed in a massive way and reproduced by means of a cloud of points.

In addition to the previous applications, other research is being carried out to check whether it is possible to analyse certain sediment transport phenomena in real time during a test. This would allow to characterize the movement of solids in a flow during the traffic of an avenue and not only the final result. For all of the above, during 2020 a collaboration has been maintained with the Department of Cartographic and Terrain Engineering of the Polytechnic School of Ávila (University of Salamanca).

- Restoration of the effects of erosion in stilling basins and river beds.
- Methodology based on photointerpretation and treatment of 3D clouds of points.

BARCELONA COMMUTER TRAINS



Contact: daniel.molina@cedex.es

CEDEX's LIF supports Alstom for the verification of the Barcelona commuter line R1.

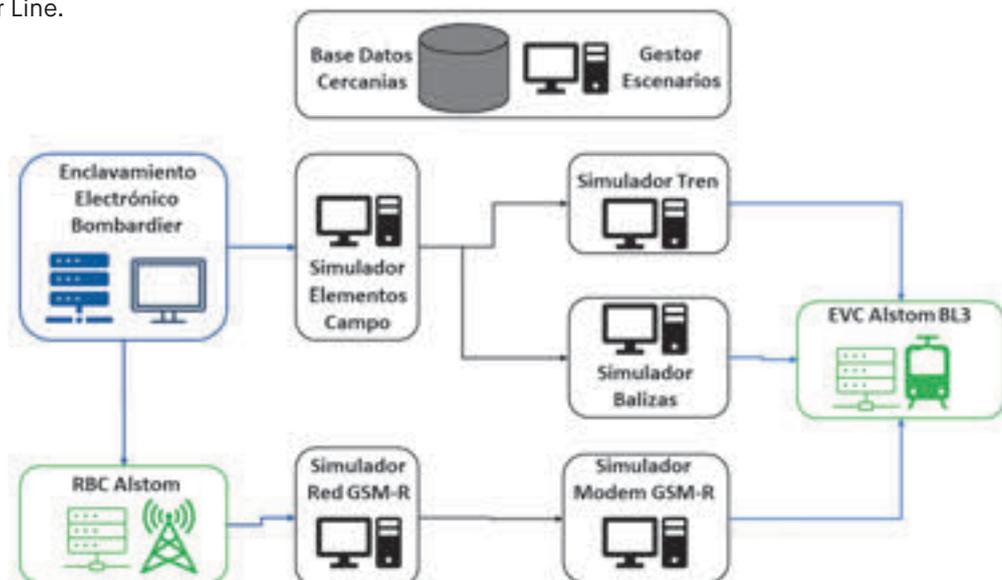


Commuter lines and trains in Barcelona are undergoing a modernization, and a ERTMS implementation process. More specifically, the line R1 has been awarded to the joint venture formed by Alstom and Bombardier to upgrade electronic interlockings and install ERTMS level 2.

In 2019, Alstom signed a contract with the LIF to support its internal tests for the verification and integration of ERTMS level 2. This support consists of the laboratory preparation and configuration, allowing its use by the Alstom staff for their internal test campaign. Also, some technical support is foreseen in case of incidences. This work has been done throughout 2020, and the results have been so positive that this formula is going to be extended to other sections of the Barcelona Commuter Network. The main laboratory tasks have been the importation of data from the line R1 section Badalona-Mataró, and the connection of the Bombardier industrial interlockings, the Alstom Radio Block Centre and the Alstom on-board unit (Baseline 3) to the laboratory simulators.

Image of Catalanian Commuter train and R1 Commuter Line.

Scheme of R1 line functioning with ERTMS



ERTMS TEST OF THE EJE ATLÁNTICO



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CEDEX'S LIF has performed, in the first semester of 2020, the train-track interoperability tests of the Eje Atlántico equipped with ERTMS L1.

The Eje Atlantico line runs along the Galician Atlantic coastline between Vigo and La Coruña for 155.6 kilometers, connecting the cities of Vigo, Pontevedra, Santiago de Compostela and La Coruña. This infrastructure is connected with the new Madrid-Galicia high-speed axis in Santiago de Compostela, whose station is equipped with ERTMS in the frame of this project.

It's a line designed to reach a speed up to 250 km/h, and it's equipped with ERTMS level 1, this is, all the information from track to train is transmitted by eurobalises.

During the first semester of 2020 the LIF has performed the last interoperability tests of this line. These tests consist of running a simulated train equipped with a real ERTMS On Board Unit (OBU), over a simulated track, which sends to the train the same telegrams sent in the real track by the eurobalises.

On this Atlantic line the track suppliers are CAF, Alstom and Siemens, and the on-board equipment used by the LIF has been the ones from Caf, Alstom and Bombardier. The combination of these track and train technologies has resulted in nine possible trak-train combinations, all of them having been tested at the LIF , and in the corresponding nine official reports sent to the client (UTE SACAT) in July 2020. The execution of the tests at the LIF led to an early detection of some interoperability incidences and, therefore, its prompt debugging before testing on the real line, with the associated cost and time reduction.

Lab tests.



GATE4RAIL (GNSS AUTOMATED VIRTUALIZED TEST ENVIRONMENT FOR RAIL)



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The GATE4Rail (GNSS Automated Virtualized Test Environment for Rail) project, funded by the Shift2Rail Joint Undertaking (JU), represents a key target for the European Commission to use safe and environmentally-friendly transport, and to promote the application of innovative and sustainable technologies.

GATE4Rail's goal is to connect the European GNSS centres of excellence to the LIF's ERTMS/ETCS laboratory at CEDEX in order to advance in the integration of satellite navigation systems (GNSS) in the ERTMS signalling system.

In the framework of GATE4Rail, a virtual laboratory has been developed to allow train simulations that process GNSS signals (for railway applications) in an ERTMS test-bed with automated test repetition and automated evaluation results.

The consortium has partners from four EU countries: Italy (RadioLabs, RFI and Bureau Veritas), France (Universidad Gustav Eiffel and GUIDE), Belgium (UNIFE y M3S), and Spain (CEDEX and INECO).

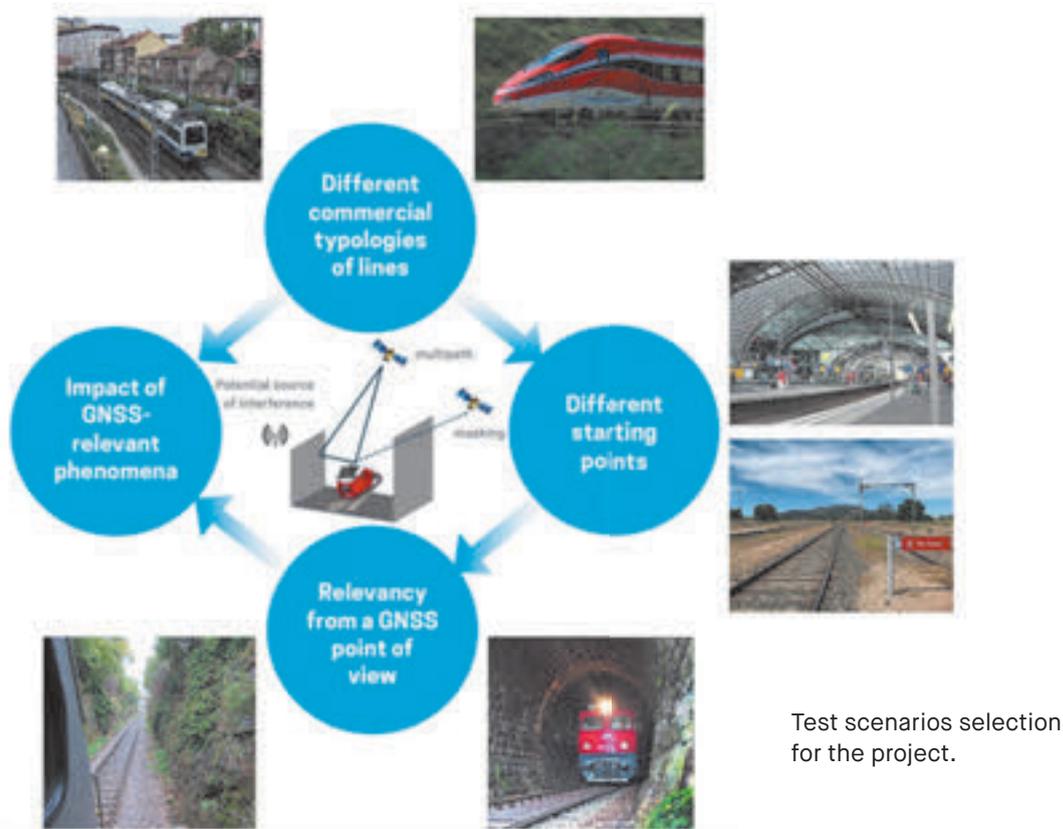
Webpage: www.gate4rail.eu

This Digital Twin has resulted in a geo-distributed simulation and verification platform with a TRL (Technology Readiness Level) of 4 for technology validated at the laboratory, and level 3 for the experimental proof of concept. The implementation based on Model-Based Systems Engineering (MBSE) has been applied in the methodology (and the associated tools) so as to perform tests and analysis in an automated way.



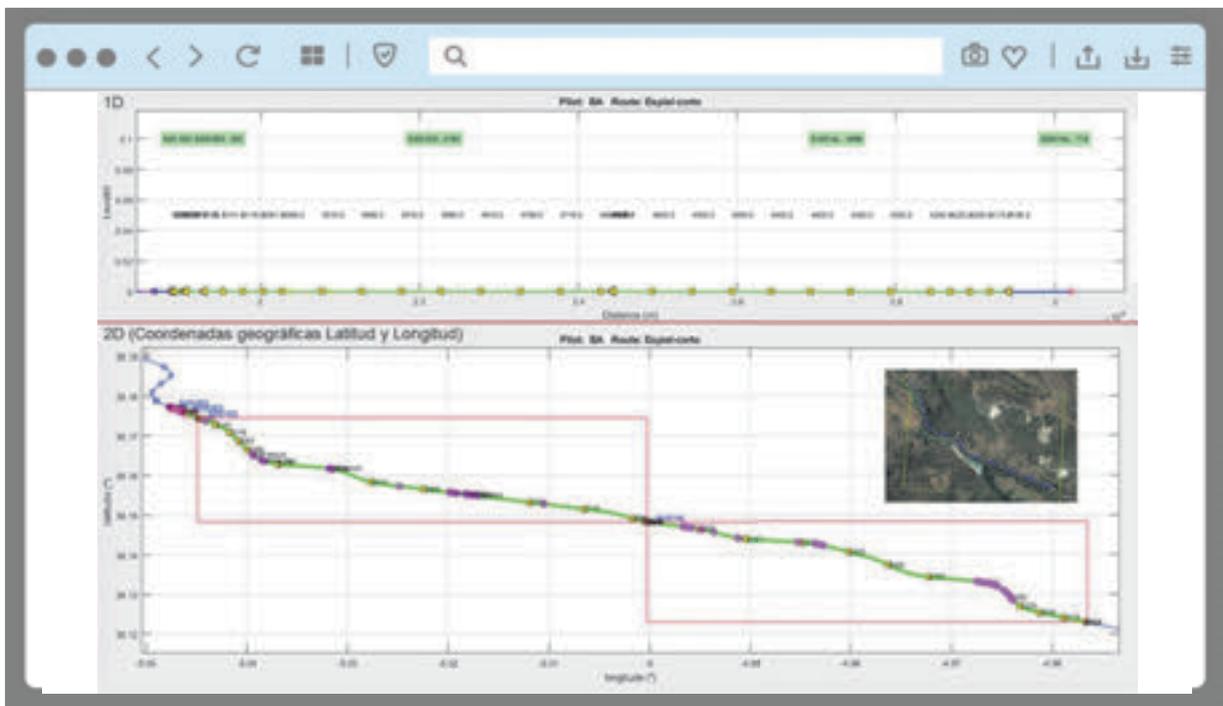
GATE4Rail is related to the following Shift2Rail goals set out in the Multi-Annual Action Plan (MAAP):

- **Fail-Safe Train Positioning:** development of safe and advanced train positioning systems by using new technologies (or sensors) that will reduce the use of trackside detection equipment.
- **Zero-on-site-testing:** minimisation of the on-site testing by the development of geo-distributed platforms that allow to standardise test methodologies, procedures and time to market.

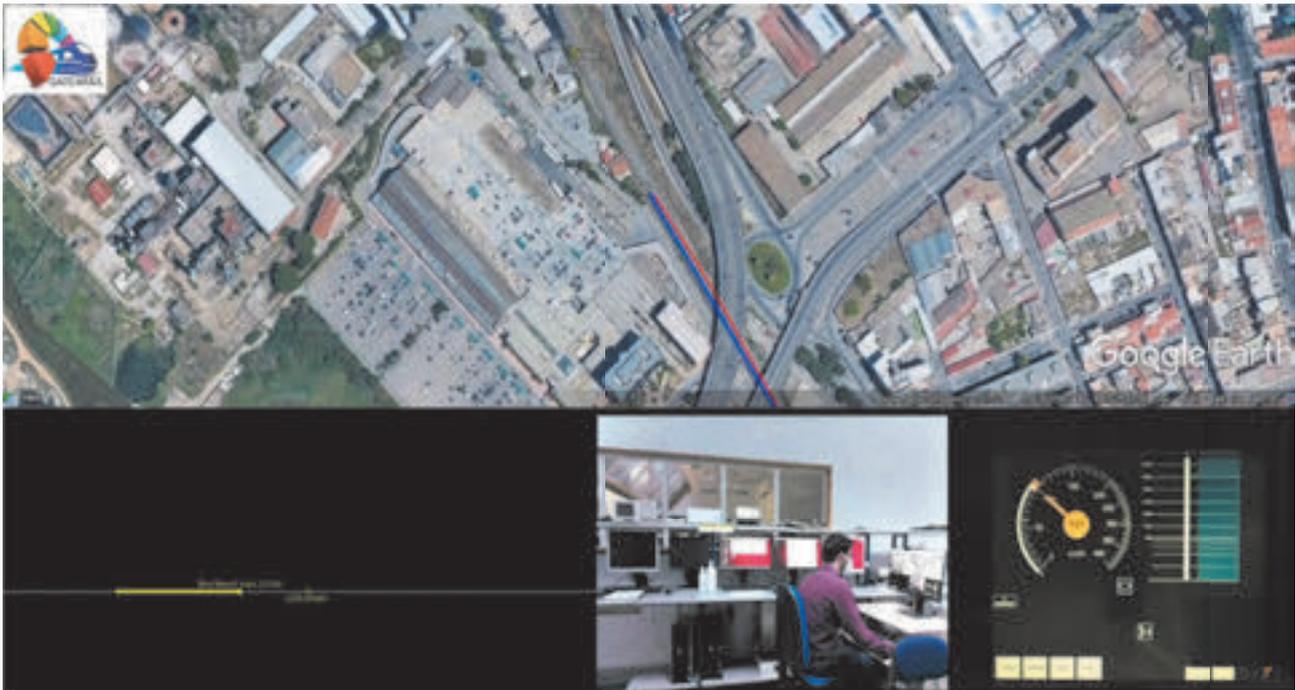


The use of this geo-distributed platform supports the integration of GNSS test cases in ERTMS, such as the design of new line engineering based on Virtual Balises, the validation of an existing line engineering, or the certification of components. In the field of

GNSS, the GATE4Rail project has defined the main features of the railway environment, and the development of a methodology for its implementation in the simulation platform under nominal conditions and in the presence of threats (global and local effects).



Representation of the virtual balises of a line section in 1-D and 2-D..



Final demonstration.

CEDEX's role has been focused on the definition of the automated test scenarios. It was also responsible for the platform implementation in terms of interfaces and format specifications (between the different modules), architecture definition at functional

and system levels, train trajectory optimisation for position and time domain, and, finally, the integration of the GNSS information into the ERTMS simulation module.

Conclusions

GATE4Rail project addresses the need to transfer field tests to the laboratory ("zero-on site testing") and the application of GNSS technology for safe train positioning.

The platform is a useful resource that provides:

- **Integration of GNSS events (realistic characterization of the railway environment) into ERTMS scenarios**
- **Evaluation of solutions based on the use of virtual balises for new or existing lines**
- **Automation of test campaigns, from the scenario definition to the generation of reports**
- **Adoption of Model-Based Systems Engineering (MBSE) approach**

In this way, the GATE4Rail project takes a step forward in the Railway Digitalization by integrating realistic GNSS satellite navigation conditions at laboratory, and by promoting the evolution of the European Railway Signalling System (ERTMS)

THE EUROCAB TEST AUTOMATION PROJECT



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At the end of 2019, after the last validation had been carried out, a Eurocab Test Automation project was started focusing on this kind of works. During 2020 the automated system has been developed and implemented in the laboratory, and currently it's being used in a new EVC validation.

Technical validation of the ERTMS/ETCS On Board Unit (OBU) conformity tests, as part of the regulatory framework of train protection system adopted at European level, is one of the works the CEDEX's LIF has lately been carrying out more often. This equipment commands the train movement and it's one of the parts of the On-board subsystem of the European Railway Traffic Management System (ERTMS). This system is designed according to the Technical Specifications for Interoperability of CCS (Control Command and Signaling). The Subset-076 is one of the mandatory specifications whose scope is to define tests to be used in providing the technical conformity and functionality of the ETCS on board subsystem against requirements of Subset-026 (System Requirement Specification).

The main reasons to develop this project were:

- Minimizing the human error that exists in a manual validation
- Rising the reliability of validation tasks with an improvement in the traceability of the results
- Helping ERTMS experts with mechanical tasks (such as the action over the driver machine interface or the gathering of the results of tests)
- The simulation of remote tests in collaboration with other European laboratories
- The need of a technological update

The diversity of HW/SW solutions given by current technology and available at user level allow us to implement systems that some years ago were not affordable due to specialization, development time and cost reasons

In order to perform the Subset-076 validation, the On Board Unit (OBU) is integrated in a Eurocab Test Bench, which is the responsible for simulating not only the train movement, but also its interaction with the trackside equipment (from balise group, euroloop and radio communication information exchange, etc.). Therefore, the behavior of the EVC (European Vital Computer) under test is similar to the one the equipment has in a real environment.

The Subset-076 includes the test cases in which the requirements of the specifications concerning the EVC are proven and the test sequences, consisting on a set of concatenated Test Cases (creating scenarios which can be run within the test environment defined in the Subset-094). The number of test sequences of the Subset-076 for validating an On Board Unit is more than 700, and with the simulation of each one, the behavior of the EVC is checked against ERTMS specifications.

The Eurocab Test Automation project envisages the use of an automatized system allowing to carry out complex lab

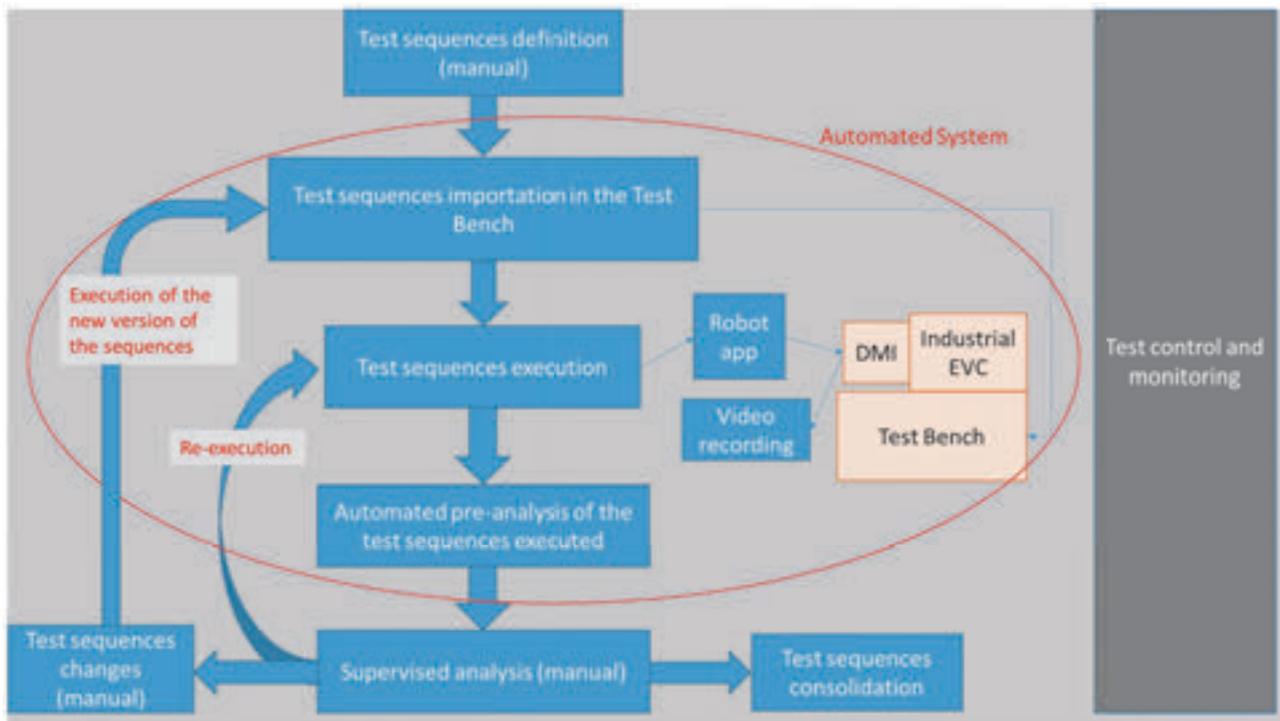


Figure 1. System structure.

tests at the laboratory on the execution, management and control phases. Moreover, it's also covered the added value of having the capacity to perform a first level analysis of test results, the so called "Pre-analysis", after the execution of Subset-076 test sequences has been already performed for a specific EVC.

The scope of the system is showed in the figure 1, in which the main modules are presented:

- The importation module
- The execution module
- The pre-analysis module

This system has been designed following modular programming approach, with the aim of reducing the dependence on bench-testing typology, letting it be useful for other lab works. All these modules are linked together so that the management layer has been developed to control the gateways between them and to get the EVC test execution traceability in the test bench. The importation module allows to set configuration parameters on

the Test Sequences to be applied on a specific EVC and to introduce the sequences in the test bench automatically.

Up to the implementation of this system, the test sequences execution needed human assistance so as to execute the driver actions over the DMI (Driver Machine Interface). Nowadays a robot (figure 2) has been designed and developed during this project to replace the train driver.

Additionally, an image recognition software was designed, in collaboration with Las Palmas University, to get and collect events showed in the DMI in order to use in the automatic pre-analysis. The pre-analysis compares the registers of the different EVC interfaces to the ones defined in each test sequence, classifying all the steps of the sequence either as "Passed" or "Non Passed", according to the results obtained.

All processes are monitored and controlled by the management layer, thereby a global view of the

This robot is able to work both in automatic mode, directly connected to the test bench and controlled by the lab during the sequence simulation, or in remote manual mode, by means of telecommand procedure, where the user controls the robot actions through a web site in real time.



Figure 2. Train driver robot.

general status of the project can be showed at any time, and the traceability of the results is guaranteed.

To manage the validation process, a dynamic web application has been created (figure 3). All control tasks and the analysis of the results can be done through this web application.

Currently, the system is being used in a new validation project and it's been a significant step forward in terms of the number of sequences executed per day, from nearly 20 sequences/day in manual optimal conditions way to more than 100 sequences/day by using the automated system.

Finally, another remarkable achievement has been the development of a system for image recognition of the DMI, and the pre-analysis of each test performed on the EVC, which has become a very useful tool for ERTMS analysis.

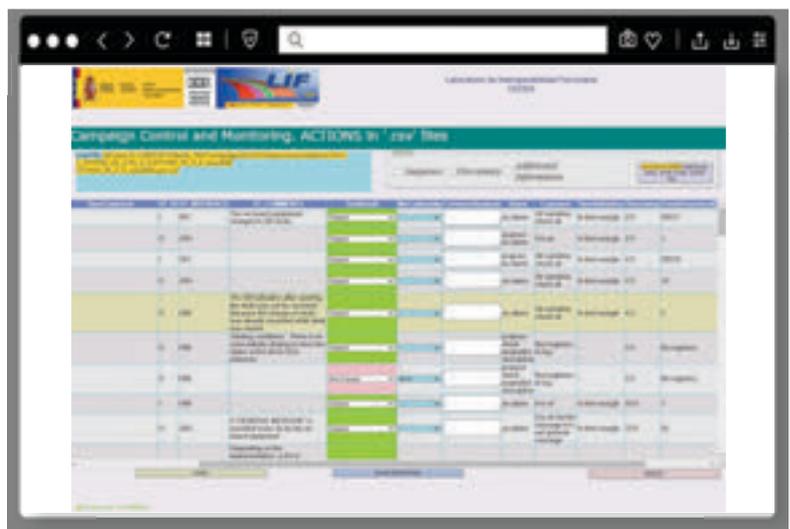
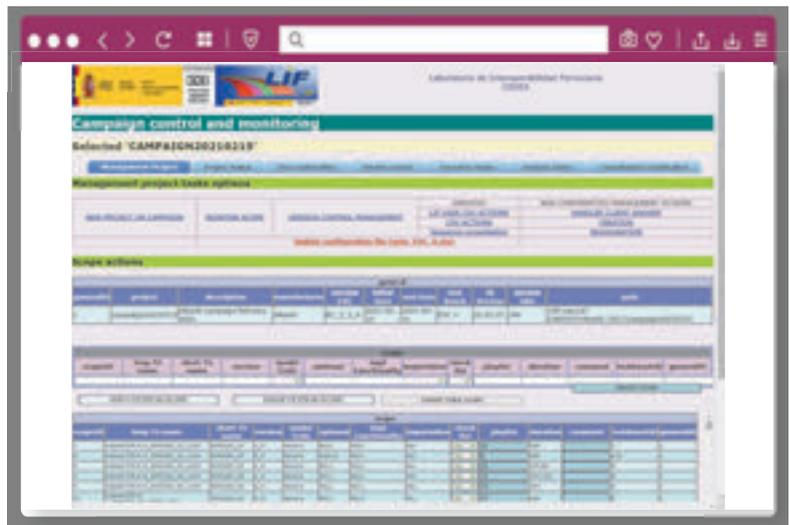


Figure 3. Web application.

STUDIES ON THE EXTENSION OF THE ESCOMBRERAS BASIN (CARTAGENA)

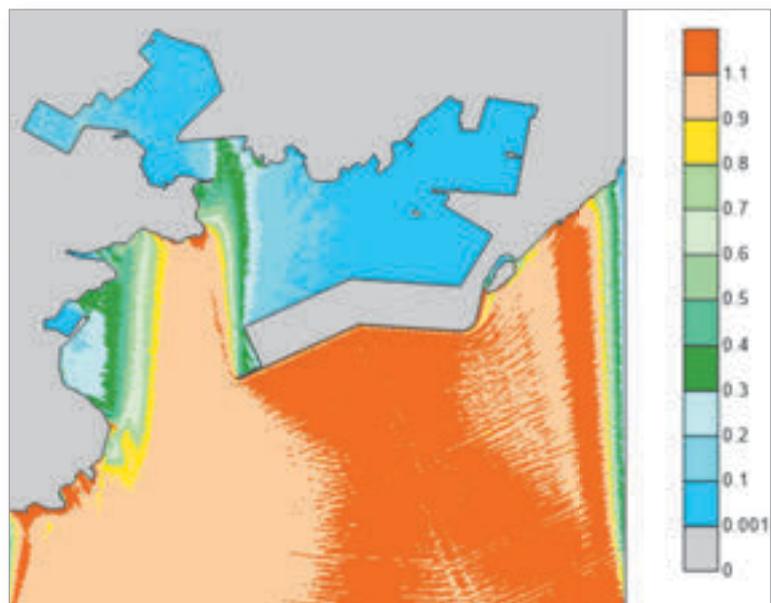


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The Cartagena Port Authority (APC) plans to expand the Escombreras Basin through the construction of a new area (esplanade) to serve container traffic, which is expected to be developed in 2 phases: the first one, attached to the current Southwest breakwater and the second one, in phase 2, that prolongs the esplanade by changing orientation, turning about 30° to the west with respect to the first one. Both surfaces will be protected by a vertical breakwater. For this reason, the Cartagena Port Authority (APC) and Puertos del Estado commissioned CEDEX to carry out, at the Center for Harbour and Coastal Studies, various studies to verify the design of this expansion, which included studies in a numerical model, physical model tests (3D) and ship maneuvering simulation studies.

Initially, the new surface area was defined in a single alignment, protected by a breakwater parallel to the current SW breakwater. On this first configuration, wave disturbance studies in numerical model and simulation studies of ship maneuvering were carried out. From the results of ship maneuver study, restraints related to navigability were detected, which were indicated by the Cartagena Pilots Corporation. This result led to the definition of a new configuration, consisting of dividing the extension into two alignments, the first (1,000 m long) in parallel with the current breakwater, and the second (1,300 m) turned to the west by 30°.

The numerical model study was carried out on the planned construction phases (phase 1, first alignment of the esplanade and phase 2 final situation of the expansion), in addition to the study on the current configuration. The results of numerical model provided satisfactory wave disturbance values in the different phases analyzed, obtaining mean disturbance coefficients lower than the





current ones. Regarding the annual exceedances of the limit wave heights defined both for the docking operations of ships and for the stoppage of loading/ unloading operations and permanence of ships in docks, they were null for the two phases analyzed, not exceeding, in neither of two alignments, the acceptable mean inoperative time, as indicated in ROM 3.1-99.

In the 1/100 scale physical model, the different phases of the projected extension were studied, by analyzing the wave disturbance inside the basin and the behavior of moored ships. The agitation results indicated that the operating time as a function of wave height is 100% in almost all areas of the port for the considered types of ship. The moored ship tests were carried out for different vessels: 2 container ships (294 and 125 m in length); bulkcarrier (103 m); oil tanker (93 m) and gas tanker (222 m). From the analysis of the results, it was concluded that with the tested situations excellent results were obtained, with practically 100% operation in all cases, except in the case

of the 135 m long container ship, in which slightly lower operation conditions were obtained, although within acceptable limits based on PIANC recommendations.

The work carried out at the Center for Harbour and Coastal Studies for this project is completed with the Real-time Ship Maneuver Simulation study, not yet completed at the end of 2020, which will also allow to verify the design from the point of view of navigability.

MANEUVERING STUDY OF LARGE CONTAINER CARRIERS IN THE NEW CONTAINER TERMINAL OF THE NORTH BASIN OF PORT OF VALENCIA



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The Valencia Port Authority (APV) is developing the project for the new North Container Terminal that will be located in the extension of the North Basin. In order to verify the viability of the access and exit maneuvers to the different berths of the future terminal for the project ship, a "Megamax" of 24,000 TEUs, the APV has commissioned the Center for Port and Coastal Studies of CEDEX to develop a ship maneuvering simulation study, which has been divided into two parts.

The first part of the study consisted of analysing the layout of the port and bathymetry (dredging area) initially defined by the APV, to verify the need to extend the current breakwater. The first part of the study has been presented in two reports, the first one with the analysis of the area occupied by the ship and the tugs in the operations and, the second one, with the analysis of safety and viability of all the maneuvers.

The safety of the maneuvers in the new configuration of the North basin and the access channel, proposed by the APV, has been validated according to the results of the simulations of the first part of the study.





"MEGAMAX" ship maneuver aided by three tugboats.

In the analysis of the safety of the access and exit maneuvers of the container ships, four meteorological scenarios has been considered, two berthing positions along the future container wharf and two different berthing options (to port and starboard) in order to analyse the difficulty of the maneuver.

The meteorological scenarios have been defined taking into account the wind and wave conditions with statistically more representative origins for the port of Valencia, with demanding wind speed and wave height values, associated with a low exceedance of hours per year.

In addition to the "Megamax" with a 430 m total length, 61 m width and 16 m draft, two container ships, representative of those currently calling at the port of Valencia, have been studied. One medium-sized with 328m length and 11,000 TEU, and another equivalent to the larger ones currently operating, with 398m in length and 16,000 TEU.

The ship maneuvering study was carried out with the POLARIS real-time ship navigation and

maneuvering simulation system, available at the CEDEX Center for Harbour and Coastal Studies.

Prior to this study, in the Port Studies Area and in the Maritime Experimentation Laboratory of the Center for Harbour and Coastal Studies, two studies have been carried out to determine the optimal length of the extension of the breakwater: a numerical model for the study of wave disturbance and a 3D physical model for the analysis of wave disturbance and moored ships.

SIMULATION STUDIES FOR THE PROGRAMMING OF SHIP ACCESSES TO THE NEW CONFIGURATION OF THE SW DOCK, PORT OF PALMA, MALLORCA



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Balearic Islands Port Authority (APB) and Puertos del Estado commissioned CEDEX to carry out a "Simulation Study of Vessel Maneuvers and Maritime Safety and Operability for a new configuration of the SW Basin of Palma Port". This communication describes the work carried out in its section "Maritime Traffic Operativity Study and Operations Programming Protocol". The aim of this work was to analyse and propose possible schedules access operations to the new configuration of the dock proposed by the APB (Alternative B1) under the conditions of the current and foreseeable traffic in the horizon of the Master Plan.

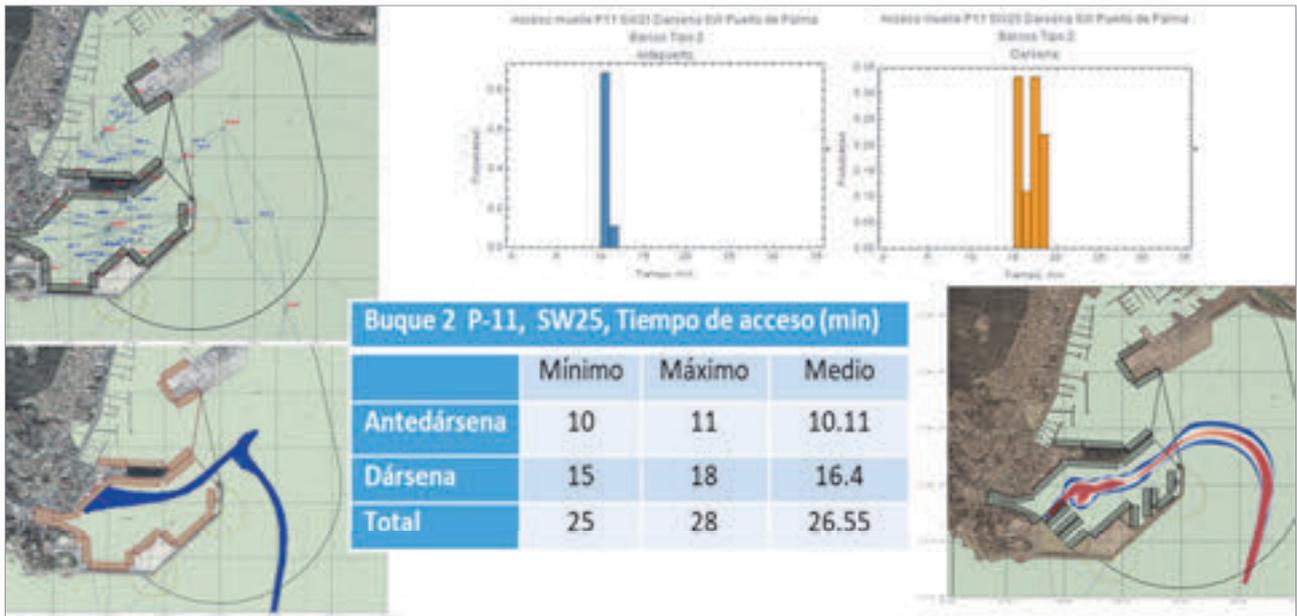
The characteristics of the logistics associated with traffic in the Port of Palma makes that, even with reduced levels of quay occupation, conflicts may arise in access to the port due to the simultaneity of entry operations in a reduced time window.

An analysis of the current traffic was carried out based on the information provided by APB and the detailed characteristics of the access operations, through the AIS historical database for analytical studies (Grassa et al., 2019) generated at CEPYC with SASEMAR data. The use of AIS data on a topological graph representation of the Port allows systemic analysis of the operations, see figure below, lower left and the statistical evaluation of access times by type of ship and dock

The characteristics of the operations in Alternative B1 were estimated from a similar analysis, executed on results of simulated access manoeuvres for different docks and vessels, obtaining the expected statistics, (fig. lower right).

Subsequently, a discrete event simulator was applied to study the access operations to Alternative B1 and to obtain possible arrival schedules.

The simulator was used to reproduce current traffic situations, taking data from the period 2014 - 2018 and others corresponding to future increases. In view of the numerical and graphical results obtained, additional simulations were run, imposing alternative schedules to improve the use of operational downtime



Graph of actual port (top left), AIS data of access to Paraires (bottom left), statistical results (centre) and simulated access paths (bottom right)

and, where appropriate, extending arrival intervals to eliminate possible delays

CONCLUSION

The use of AIS data in existing situations or equivalent simulation information together with a sea area graph provides concise descriptions

of nautical operations to feed discrete event simulators applicable to studies of sea area use in maritime-port design or management and its environmental aspects. This combination of techniques has made it possible to study the effect of a port modification on the access development operations and propose specific traffic schedules for each alternative.



Aerial view of the Palma de Mallorca Port.

ASSESSMENT AND MONITORING OF THE REGIONAL AUTHORITIES' WORKS IN THE FRAMEWORK OF THE PLAN "PIMA ADAPTA COSTAS"



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Since 2015 the Ministry for the Ecological Transition and the Demographic Challenge is implementing a National Plan for environmental protection including climate change adaptation that is coordinated by the Spanish Office for Climate Change (OECC). In 2017, within the framework of this Plan, OECC reached an agreement to task regional authorities with developing a set of studies where climate change risk assessments in coastal areas will be addressed. In this context, CEDEX has been commissioned by OECC to monitor and evaluate the deliverables from the regions.

One of the major task to perform by CEDEX in the coordination process with the Regions, was focused on technical specifications for the data sets to collect and report. A number of indicators were defined for data regarding installations, including critical infrastructures, land uses, natural resources, and vulnerable activities to climate change, finally compiled in Geodatabases.

Furthermore other relevant data sets for a suitable physical and biological characterisation of the land closed to the sea and transitional waters were integrated, in particular high resolution digital elevation models.

During the period 2018-2020, CEDEX has been working with Regions adopting criteria for the data required for risk analysis as well as in the definition of the information exchange process. As a result, a great source of updated data, extremely useful, is now available not only to evaluate climate change effects in coastal but also to develop other projects aimed at shore protection or integrated coastal management.

On the basis of the information collected, jointly with the study of marine dynamics for different climate change scenarios, including sea level rise (RCP4.5 (+0,45 m) y RCP8.5 (+0,65 m)), Regions are currently engaged in risk assessment analysis with final results expected in 2021.



View of the beach erosion and seawall collapse, Mongat (Barcelona) after the storm Gloria.

Coastal Flooding maps, highlighting mostly affected councils, shore erosion calculations including estimation of surface loss in beaches, expected morphological changes in estuaries, identification of infrastructures potentially damaged by the effect of climate change and an estimation of economical loses in the different scenarios are an example of the products to deliver.

Once the risk assessment studies from the Regions were completed, CEDEX will analyse and assess the rate of comparability and consistence among them taking into account the Pilot Project developed in Principado de Asturias Region that will be documented in a report for the consideration of OECC.

INFOMAR: INFORMATION SYSTEM ON THE MARINE ENVIRONMENT



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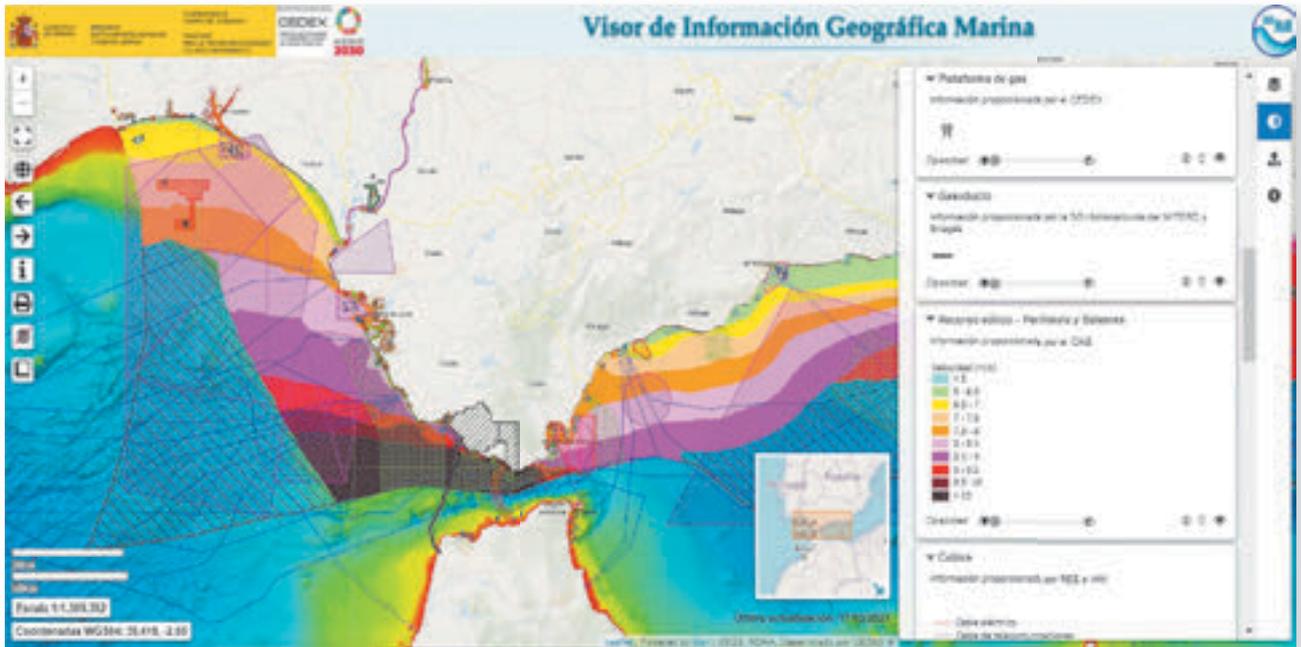
INFOMAR is an application designed and developed by CEDEX for the Sub-Directorate for the Protection of the Sea in order to facilitate the generation, collection and analysis of information on the marine environment as well as in the publication, dissemination and reporting of the same. This system is accessible through the web site infomar.cedex.es. Its geoviewer is being a crucial tool supporting Maritime Spatial Planning in Spain.

The activities carried out by the Sub-Directorate for the Protection of the Sea (SGPM, Directorate General for the Coast and the Sea, Ministry for the Ecological Transition and the Demographic Challenge) lead to the generation and use of a volume of data very remarkable. Its correct management and interpretation are of vital importance for the decision making process. Likewise, the reporting of data and data products to the European Commission and their dissemination/communication among stakeholders and to the general public are also tasks to be effectively performed.

To achieve this, the SGPM promotes the creation of INFOMAR, an application for the management of the information that the SGPM finances or requests in the



INFOMAR web site.



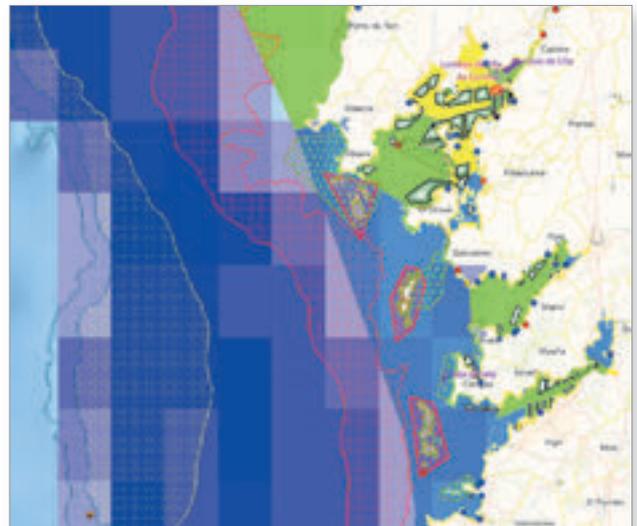
Marine geoviewer. Uses and activities in Cádiz Gulf and Gibraltar Strait.

development of its competences. The Centre for Harbour and Coastal Studies (CEDEX) is the organism in charge of the design, development, updating and maintenance of INFOMAR.

INFOMAR consists of different tools. The first one is the data entry forms. Information that was previously reported in text documents will be dumped directly into structured forms connected to databases. This process increases consistency and reduces the time required for processing and interpretation.

A metadata catalogue is the second tool implemented. It allows locating data sets related to the marine environment generated by units or institutions of the General Government Administration easily.

Of special interest is the marine geoviewer, which is proving key in the maritime spatial planning exercise. It allows detecting synergies or conflicts between uses or with the protection of species or habitats, as well as identifying the most suitable areas for developing certain activities, promoting blue growth.



Uses and activities in the Rías Baixas Region.

Finally, there will be a section on accessing and downloading the data sets generated for the implementation of the Marine Strategies, which is still pending of development.

INFOMAR is part of the digitization of the Public Administration, and it will become the reference application on marine information in Spain.

PLAN FOR THE PROTECTION OF THE DELTA OF THE RIVER EBRO



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This work is part of the set of strategies for the protection of the coast of the General Directorate of the Coast and the Sea, and is added to other previous strategies of the coasts of Huelva, Granada, Valencia, Castellón, Barcelona and the Mar Menor. The Plan has been prepared jointly with the General Directorate for Water and its objective is the environmental recovery of the Ebro Delta, whose situation has been aggravated in recent years, especially after the passage of the “Gloria” storm in January 2020.

The management of the Ebro Delta is complex and needs a solid balance, based on the different action plans, both derived from the management of the coastline, as well as from the management of its natural spaces and the uses of the Delta -especially of the fishing and irrigation- and the hydrological management of the Ebro river and tributaries, even more affected by climate change.

All of this has motivated the Secretary of State for the Environment to promote the "Plan for the protection of the Ebro Delta", which includes both actions in the river Ebro and actions on the coast, and with which it is intended to promote and facilitate its public use, as well as maintaining the environmental values of the Delta, taking into account the challenges posed by climate change, in particular the rise in sea level.

The General Directorate of the Coast and the Sea (DGCM), the General Directorate of Water and the Ebro Hydrographic Confederation have participated in the elaboration of this Plan, with the technical and scientific support of CEDEX, the latter through the Centre for Harbour and Coastal Studies, the Centre for Hydrographic Studies and the Centre for Applied Techniques Studies.

All these organizations are working together, to develop in the short, medium and long term different actions that allow to improve or manage the problems derived from the management of the Delta at present and in the face of the effects of climate change.



Proposal for sediment management actions in the North part of the Delta.

The Plan describes the main environmental values of the Ebro Delta, a task carried out by the CEDEX Centre for Applied Techniques Studies. In the fluvial field, the Plan has been drawn up by the General Water Directorate, with the collaboration of the CEDEX Centre for Hydrographic Studies, giving rise to the "Action Plan for the improvement of the management of the sedimentary regime in the field of Ebro Delta". It should be noted that this Plan will form part of the Hydrological Plan of the Ebro basin of the third cycle, for which a series of conclusions and lines of action are established that are formalized in a "roadmap" to improve sedimentary transit in the basin in the coming years.

Finally, in the maritime field is framed the "Plan for the protection of the coastline of the Delta of the river Ebro", prepared by the Centre for Harbour and Coastal Studies under the direction of the DGCM, and which proposes a set of actions throughout of the coast of the Ebro Delta for its protection and environmental improvement, which addresses the challenges posed by climate change, in particular the rise

in sea level. The proposed actions can be summarized in the following points:

1. Preparation of a new demarcation incorporating the lands that have characteristics of Public Domain.
2. Realization of a protection strip that allows the free movement of the coast.
3. As an additional action, execution of four possible sand transfers, two in each part of the Delta (see figure 1).

UPPORT TO MITERD FOR COMPLIANCE WITH THE ENVIRONMENTAL NOISE DIRECTIVE



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 Ruido ambiental

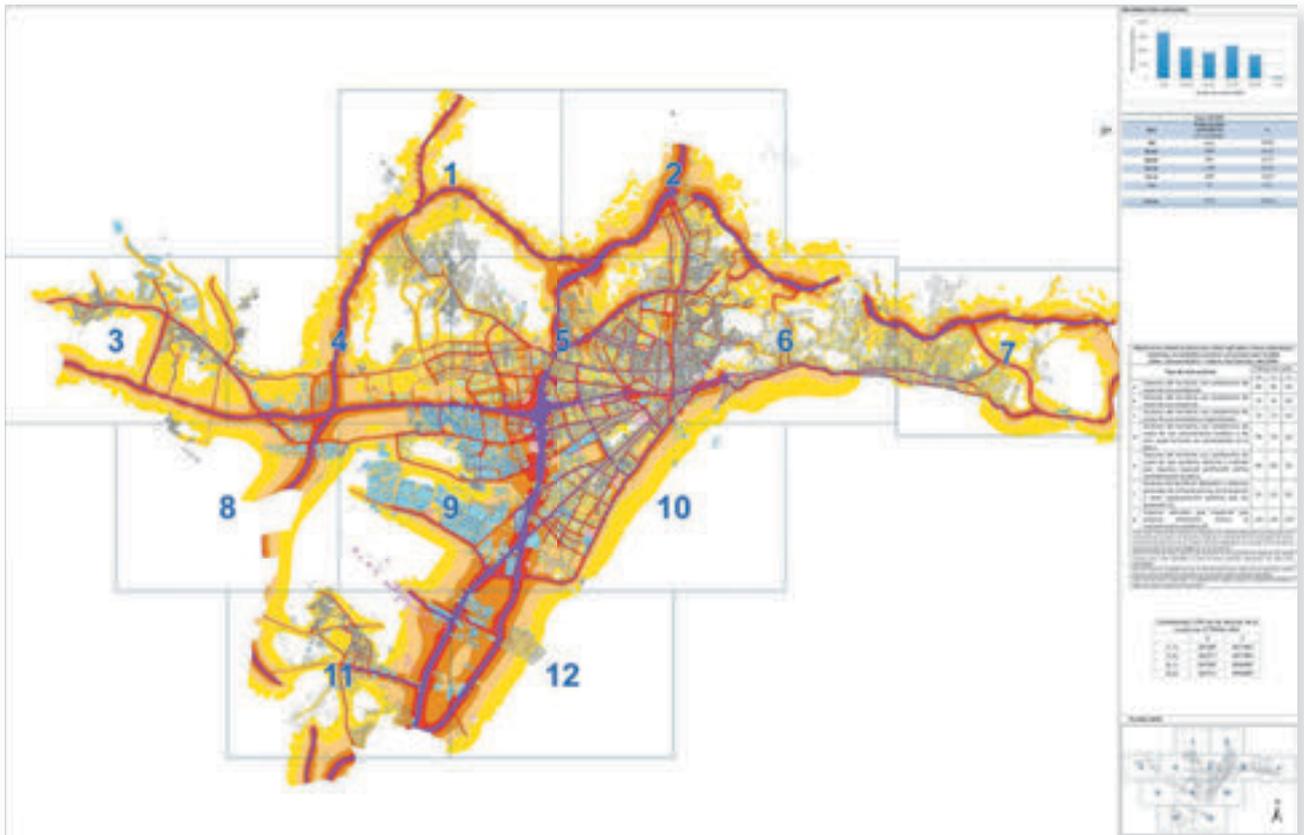
The Cedex Environmental Noise Area carries out its fundamental activities in the field of environmental noise assessment and management and its relationship with land use planning and transport infrastructure planning. During the last years, an important part of the work carried out has focused on the development of methodologies for the evaluation and communication of environmental data within the framework of the implementation of the END and INSPIRE Directives, acting as a reference center for the Central Administration. This Area is also a part of the European Commission Noise Regulatory Committee.

During 2020, the work of the Environmental Noise Area has focused on complying with the new legal requirements established by the European Commission for the preparation and submission of Strategic Noise Maps and Action Plans against Noise data in the fourth phase of compliance with Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise.

The main tasks have consisted of:

- Analysis of compliance with the third phase of the Environmental Noise Directive by the competent authorities of the Kingdom of Spain.
- Establishment of guidelines for elaboration and communication of maps and plans, according to the requirements of the new data model for the reporting of results (Repornet 3.0)
- Maintenance and updating of the National Information System on Noise Pollution (SICA)
- Evolution of the National Information System on Noise Pollution (SICA) towards a national spatial data infrastructure for Environmental Noise, which offers the services required by Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE)
- Attendance, as advisers to the Ministry for the Ecological Transition and the Demographic Challenge, to the meetings of the Noise Expert Group and Noise Regulatory Committee, in which the new European regulations on Environmental Noise are debated and approved.

In 2020, the Cedex Environmental Noise Area has also



participated in the 2020 National Acoustic Congress (Tecniacustica'20), with the following communications:

– Ramón Querol Herrá, Ignacio Soto Molina, Fernando Segué Echezarreta (2020). *Third phase of application of the directive on evolution and management of environmental noise. Compliance and exposed population data.*

Acoustics 2020 – Tecniacustica'20. E-Congress. Portugal. October 2020.

– Ignacio Soto Molina (2020). *Environmental noise spatial data infrastructure in Spain. Opportunities, needs and content.* Acoustics 2020 – Tecniacustica'20. E-Congress. Portugal. October 2020.



Corredor del Cadagua, BI-636, Zamudio (Vizcaya).

WATER TIGHTNESS CONTROL OF THE RIGHT-HAND BANK OF THE TOUS RESERVOIR (VALENCIA)



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The objective of this study has been the assessment of water tightness of the geologic substratum of the right-hand Júcar river bank at the Tous reservoir, located in a karstic area affected by geologic faults.

This work was performed in 2019 and 2020 for the Júcar River Basin Authority. It included an analysis of continuous piezometric and hydrometric records from boreholes and springs integrated with a study of environmental isotopes (deuterium, oxygen-18 and tritium) under different hydrologic moments. A review of historic records of the database existing at CEDEX about isotope composition of precipitation, rivers, reservoirs and aquifers in the study area was also performed and showed to be decisive in the correct interpretation of the problem.

Deuterium excess and tritium activity were the best indicators of water tightness of the geologic substratum of the right-hand Júcar river bank at the Tous reservoir, and the best tracers of the "fingerprint" of the water potentially leaking from the reservoir to the surrounding groundwater bodies located downstream. According to both indicators no sign of water from the reservoir have been identified in the groundwater in this river bank. This observation has been confirmed when the water reaches its highest level in the reservoir, as well as in extreme meteorological situations corresponding to heavy rainfall and dry periods of low water levels in the aquifer.

Karstic aquifer of the right-hand Júcar river bank downstream the Tous reservoir (Picture: Miguel Ángel Pérez).



STUDY OF THE IMPACT ON INSECT COMMUNITIES IN RURAL AND URBAN SECTIONS OF HIGHWAYS



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This project focuses on the effects of highways on insect populations. To assess this impact, we took samples with an innovative insect collecting system that is installed on a vehicle (you can see how it works at <https://twitter.com/Carreteras/status/1107579119506804736>). We have observed that as the volume of traffic increases, the number of insects on highways decreases, contributing to the decline of their populations.

When analyzing the number of *Diptera* (flies, syrphids, etc.) and *Hymenoptera* (bees, bumblebees, etc.), a traffic intensity threshold of about 6,000 vehicles/h was detected. Below this threshold more Hymenoptera are collected, above this threshold more Diptera, which can be attributed to the different behavior of each order on the road. The β -diversity was studied in the stretches of agricultural areas. In the relationship between insect communities inside and outside the highways, species turnover seems to predominate in general, but abundances inside and outside tend to balance. These results indicate that the highway functions as a barrier for some species and as a filter for others.

Diptera and Hymenoptera

They are the two most important orders of pollinators and also the most road-killed. Hymenoptera are territorial and may establish their home range along roadsides.

β -diversity

With β -diversity we know the degree of change and replacement in terms of species composition and insect abundance, between communities inside (under the effects of traffic) and outside (without traffic impact) the highways.



A



B



C

Bombillids (A) and syrphids (B) are very efficient pollinating dipterans, like bees (C).



Installation of the insect collectors before the start of sampling.

INNOVATION IN APPLYING ENVIRONMENTAL TRACERS AND ISOTOPES IN HYDROLOGY



Contact: javier.rodriguez@cedex.es / emilia.jimenez@cedex.es

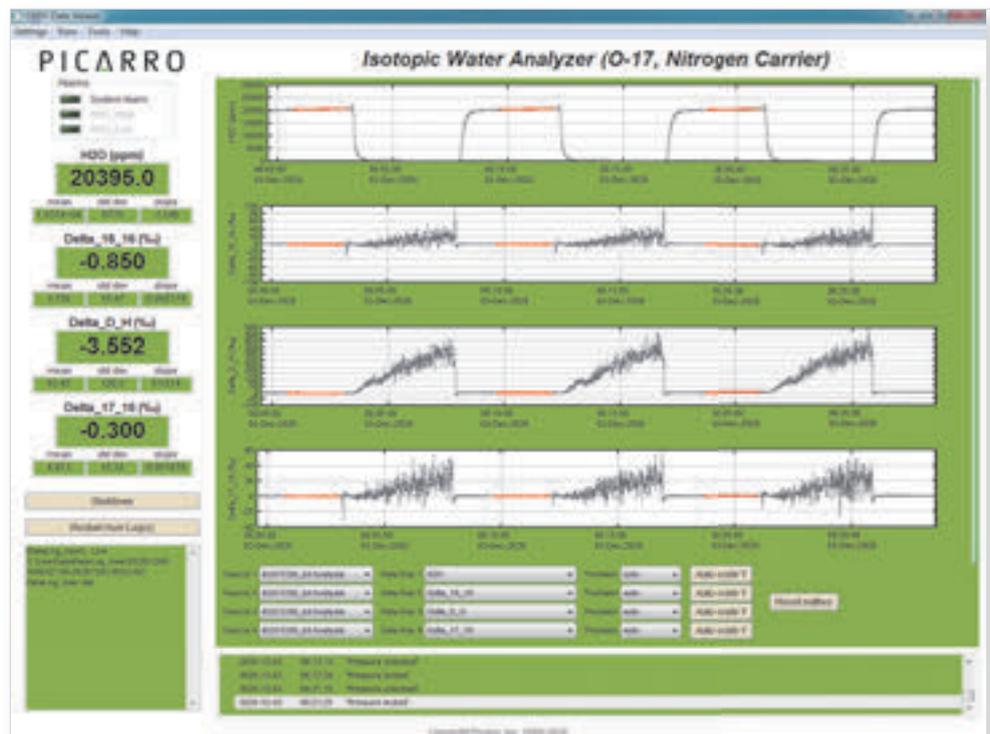
This project proposes the study of hydrological systems of the national territory, selected among those with isotopic information available, using new tracing, dating, spatial modelling, geostatistics, precipitation-runoff analysis and mass balance techniques. The main goal is to gain a deeper understanding of water cycle components, for a better interpretation of their interactions, and processes involved in its role of ecosystems supporter. It is also intended to expand the scope of isotopic studies to fields of interest closely linked to water cycle like climate change.

Changes in the isotopic composition of water in the water cycle occur primarily during the passage of water into and through the atmosphere. The specific isotopic signatures engendered by these processes are then imprinted on the terrestrial water bodies. The isotopic "fingerprint" of water can help to trace several hydrological processes of interest (evaporation, recharge, mix) for studies on water quantity or quality in a catchment basin.

For decades, the Area of Isotope Applications (AAI) of CETA has been using isotopic and tracer techniques to detect dam leakages, assess groundwater recharge and study the origin of pollutants in both surface water and groundwater masses. The large isotope database of the water cycle in Spain, which contains data mainly of $\delta^{18}\text{O}$, $\delta^2\text{H}$ and activity of ^3H in precipitation, rivers, reservoirs and aquifers, is taken as the starting point of this project.

Laser spectroscopy for triple analysis ($\delta^2\text{H}$, $\delta^{18}\text{O}$ and $\delta^{17}\text{O}$) in liquid water and atmospheric vapour.

Analytical capacities of AAI for water cycle characterization are expanded by the development of new procedures based on laser spectroscopy. This technique provides direct data on a new tracer candidate (^{17}O) and a new component of the water cycle (atmospheric vapour).



OPERATIONAL MODELING OF DISPERSION OF AIR POLLUTANT EMISSIONS BASED ON SAMOA



Contact: laura.crespo@cedex.es

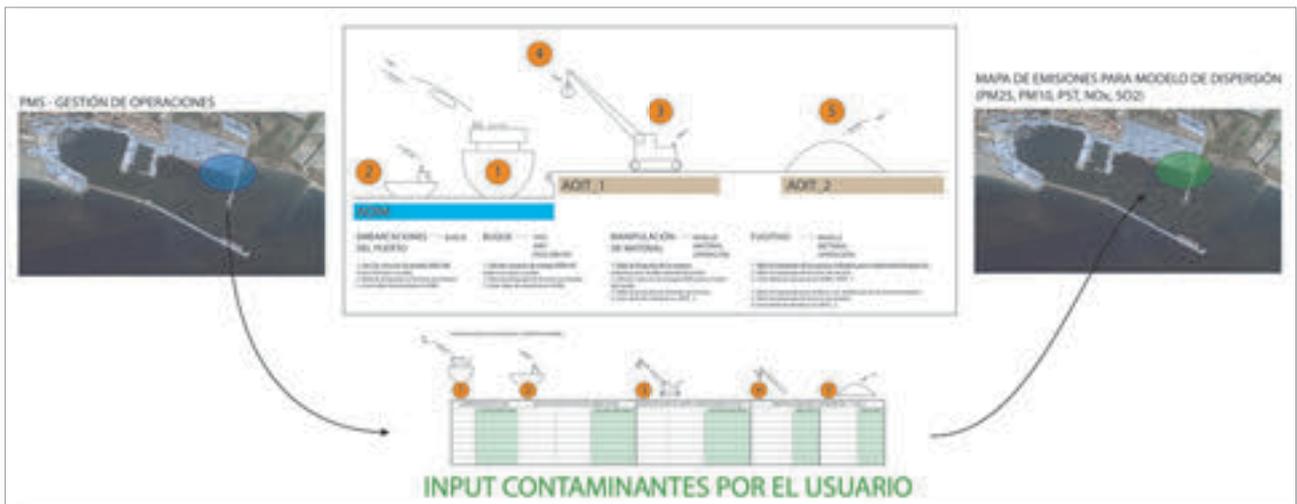
CEDEX, in collaboration with Puertos del Estado (PE), the wind engineering company Oritia & Boreas and 16 Port Authorities, is working on the implementation of an operational modeling of dispersion of atmospheric pollutants within the SAMOA project in each of the ports managed by the aforementioned authorities.

The project begins with the modeling of the physical port environment, which incorporates information on air pollutant 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 into a tool to know in advance how cities that are close to ports environments are affected by atmospheric pollution caused by port activities.

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 project: Motril, Almería, Carboneras, Málaga, Huelva, Vigo, Avilés, Gijón, Tarragona, Sagunto, Valencia, Gandía, Cartagena, Alcudia, Sta.Cruz de Tenerife and Granadilla)
- Wind engineering specialist company (Oritia & Boreas)
- CEDEX

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 air pollutant 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 filled out 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.



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

CARBON FOOTPRINT CALCULATION IN PORTS AND ATMOSPHERE POLLUTANT EMISSIONS INVENTORY. CASE STUDY: PORT OF SEVILLE



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CEDEX, in collaboration with Puertos del Estado (PdE) and other Public Administrations, prepared the Methodological Guide for carbon footprint calculation in ports, which is accompanied by a practical example applied to the port of Vigo.

In 2018 this methodology was applied to the port of Cartagena, advancing in the knowledge to calculate the emissions not only of GHGs associated with port activities but, in addition, the calculation was extended to other atmosphere emissions of polluting gases such as: SO₂, NO_x, PM-10, PM-2.5, NMVOC and metals.

In 2020, the Methodological Guide for carbon footprint calculation in ports was revised, updating the emission factors, the average consumption of vehicles and adding the calculation of emissions assigned to pipeline transport as the most remarkable modifications.

Also in this year, Atmosphere Emissions Inventory of the Port Authority of Cartagena was revised to adjust the content to a Web page format.

Following this work line, it has been proposed to start the Carbon Footprint calculation in the Port of Seville, taking as reference the Methodological Guide for carbon footprint calculation in ports and the Emissions Inventory of the Port Authority of Cartagena.

The preparation of the Methodological Guide for Green Public Procurement in Ports has been launched, with emphasis on reducing the carbon footprint of these infrastructures.

Working group that supervises Carbon Footprint calculation methodologies:

- Puertos del Estado (PdE)
- Port Authorities
- Spanish Office of Climate Change
- Ministry of Transport, Mobility and Urban Agenda (Prospective and Analysis Area)
- Representatives of the scientific and university community
- Business organizations and private certification companies
- Examples of ports for carbon footprint calculation: port of Vigo and port of Cartagena

Photovoltaic installation installed on the roof of the Maritime Station of the Port of Almería.



STUDY OF ALTERNATIVES FOR THE INTEGRAL RESTORATION OF THE VINALOPÓ RIVER



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The cooperation agreement that was signed by the Generalitat Valenciana and CEDEX aimed at the production of a detailed technical study, which included the assessment of the current status of the Vinalopó River basin, as well as the proposal of a range of measures for an integral environmental recovery. In particular, this initiative focuses on the promotion of natural processes, habitats and ecosystem services that are provided by the fluvial system.

Natural section of the Vinalopó River, downstream of Elda, where a strong incision of the river bed can be seen (January 2020); ii) Concrete-lined section of the Vinalopó River as it passes through the urban section of Elche (January 2020).

Through a combination of field and desktop work, the characterisation of the entire course of the Vinalopó River (hydrology, geomorphology, ecology and ecosystem services) has been carried out. Results of the study highlighted the urgent need to reverse the historical degradation that the river basin has undergone, and served as the basis for the proposal of the recovery objectives. In addition, a wide range of measures were put forward with the aim of achieving the proposed recovery objectives.

These measures included:

1. the review of concessions and the redefinition of the ecological flow regime;
2. the quality improvement of wastewater treatment plant effluents, and the inspection of discharges;
3. the maintenance of riparian vegetation and the control of invasive alien species;
4. the renaturalisation of urban and peri-urban stretches, and the adaptation or elimination of transverse or longitudinal obstacles;
5. and the promotion of programmes for environmental awareness and education, monitoring and assessment.



Study area: Vinalopó River (length ≈ 81 km).

High level of degradation of the fluvial system and of the river-aquifer connection.

Multidisciplinary approach of the proposed measures.

Adaptive management will increase the resilience of the river system to future changes.

METHODOLOGICAL FRAMEWORK FOR THE CLIMATE CHANGE ADAPTATION ANALYSIS OF TRANSPORT INFRASTRUCTURES



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In the context of State infrastructures, it is necessary to define a methodology that analyses infrastructure vulnerabilities in the face of the weather and that is capable of anticipating changes in the entire transport system.

Analysing current vulnerabilities and those derived from the effect of Climate Change is key in risk analysis. In vulnerability and risk analysis methodologies, climatic variables that affect transport infrastructures are taken as a starting point, with their climatic indices (aggregated climatic variables) according to different climatic scenarios.

Input data and climatic indices (climate projection) of the study area overlap with the information from the infrastructure, that is considered and valued as a heritage asset and that belongs to a transportation system, which has a set of elements that provide a service to the community.

Both, vulnerability analysis and risk analyses that come from this methodology allow obtaining quantitative information and maps of the most vulnerable infrastructures, providing an inventory of assets and services at risk due to possible current and future impacts.

To achieve this objective, the following scheme is proposed:



1. Consider the vulnerability of a project and the Critical Transport network facing climate variability. Phase 1 (Vulnerability Analysis).
2. Assess current and future climate risks. Phase 2 (Risk Analysis).
3. Identify the most cost effective adaptation options and integrate adaptation measures (resilience measures) into the project life cycle. Phase 3 (Adaptation Plan).
4. Develop a Plan that highlights the need for monitoring actions and the response to the operation of the measures. Phase 4 (Monitoring Plan).

This methodology should analyse “infrastructure criticality”, a concept that refers to structures or sections of the transport system that are crucial to perform the transport services of a community or region. For



City of Madrid, with limited mobility, due to the storm FILOMENA.

this reason, the redundancy of the different infrastructures must be evaluated. Criticality is a value related to the functionality of the transportation system and to the definition of the essential services provided to the community.

In a coordinated manner, and in collaboration with the rest of the CEDEX Centres and Laboratories, CETA and CET are working on this methodology, aligned with the National Plan for Adaptation to Climate Change (PNACC) 2021-2030. Its implementation will require the participation of different units, administrative centres, companies, entities and ministerial departments for an effective implementation in the entire transport system.

DIGITISATION OF CIVIL WORKS BY 3D SCANNING AND BIM MODELLING: A CASE STUDY OF THE LCEYM TEST BUILDING



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R&D&I project on Digitisation of civil works by means of 3D scanning and BIM modelling. A first case study for adapting regulatory standards to pre-existing infrastructures.

CEDEX is currently **implementing the BIM (Building Information Modelling) Methodology** in its centres. However, this implementation isn't straightforward, as we're working with unique buildings that have been in use for decades, and the available documentation is therefore insufficient. Therefore, a prior step is necessary: **digitise these construction and engineering works by 3D scanning, and BIM modelling** to obtain a digital twin to work on accurately.

Through case studies, **BIM standards and norms are analysed to adapt them to existing structures and buildings.** The objective is to define the methodology for accurately capture reality, and introduce linked information and BIM modelling for subsequent use as an advanced structural analysis model.

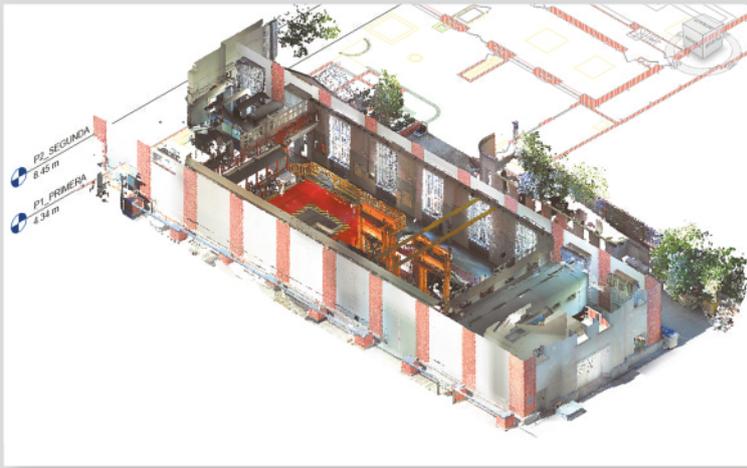
This first study, initiated in 2020, consisted of **modelling the LCEYM test building.** This was done by using the 3D laser scanner, and processing software from CEPYC and Revit licences purchased by CEDEX.

The study allowed for **the testing of capture, shot analysis and modelling techniques.** First, a workflow was established to organise captures, process data and extract information. The rigour of the survey (CAD, BIM and laser measurer) was then evaluated, resulting in relevant differences and higher accuracy in favour of the BIM model. Finally, the results were presented to the CEDEX team, generating great interest, which has led to the CEPYC proposal to carry out the second study on their test building.

This project is aligned with the objectives of MITMA's Digital Transformation Plan and the Integrated Maintenance Plan for buildings and facilities.

BIM Methodology Implementation

1. 3D Survey:
Scanning + Photogrammetry + Data
2. Digital Information System:
Geometric survey +
BIM Information Model
3. Unified model:
BIM MODEL
↓
Structural analysis



3D point cloud.
Axonometry and interior
of the test building.



BIM model.
Axonometry and interior
of the test building.



AGREEMENT BETWEEN THE LOCAL PUBLIC BUSINESS ENTITY BALSAS DE TENERIFE (BALTEN), THE INSULAR COUNCIL OF AGUAS DE LA PALMA (CIALP) AND THE CENTRE FOR STUDIES AND EXPERIMENTATION IN PUBLIC WORKS (CEDEX)



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The Agreement includes the collaboration between the three entities to carry out studies on the evolution of synthetic materials used in the waterproofing of reservoirs on the Canary Islands, as well as the study and research of this type of materials installed in an experimental field located in the south of Tenerife Island.

The development of the agreement implies the sampling of geomembranes that waterproof the infrastructures located on the islands of Tenerife, La Palma and El Hierro by the personnel of BALTEN and CIALP; the study and experimentation of the performance of these materials at CEDEX facilities; and the carrying out of joint tasks, both for analysis and for the preparation of particular and general conclusions, all resulting in the corresponding and



Puntagorda reservoir. La Palma.



Montaña del Arco reservoir. La Palma.

Agreement BALTEN, CIALP and CEDEX

- Reservoirs on the islands of Tenerife, La Palma and El Hierro
- Totality of 37 reservoirs
- Geomembranes: PVC, HDPE and EPDM
- Study running on for over 30 years

reciprocal transfer of knowledge among the personnel of the three institutions.

BALTEN and CIALP carry out the compilation of technical information on geomembranes and their evolution over time. They also carry out the tasks of extracting material samples with the periodicity determined in the agreement, sending them to the Central Laboratory for Structures and Materials for study. CEDEX, for its part, carries out technical inspection visits to the reservoirs on an annual basis, as well as the study and evaluation of the state of degradation of the waterproofing geomembranes.

The collaboration between CEDEX, BALTEN and CIALP, running on for over 30 years, represents an internationally recognized research study in the field of waterproofing. The experience acquired in the study of the performance of different waterproofing materials has been published in different forums, and has served to develop test methods included in the Spanish regulations.

LARGE-SCALE IN SITU TEST FOR MEASURING THE PERMEABILITY OF THE EARTHFILL OF ALCORLO DAM (TAGUS RIVER)



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The following in situ test is part of the commission for assistance to the Directorate-General for Water (DGA), in this case, at an earthfill dam (Alcorlo, Tagus River), as a result of the concern of weathering features of the fill (prone to "crumble") at the upstream slope. The Geotechnical Laboratory (GL/LG) studied this issue of weathering in 2011. As the DGA had later received a report that suggested that a rapid drawdown might put at risk the stability of the dam (note that the permeability of the earthfill was presumed here to be $k \approx 0,01$ cm/s), the GL suggested a purpose-built permeability test at the site.



Performance of the test, ditch of 1 x 1 m.

Although tests with similar objectives are reported (Matsuo and Haefeli tests), they aren't standardized and are somewhat empirical. The GL, then, took the Vedernikov solution, described by Harr (1990).

As shown, it's a 2D seepage from a ditch. It's worth noting that the gradient reaches $i=1$ in these "percolation" problems, and that the seepage turns soon downwards and tends to a constant "seepage area". Setting up this model at the upstream slope of Alcorlo dam needed prior levelling and pumps capable of supplying a flow rate that would maintain the water level at the ditch. The calibration was carried out at the Centre for Hydrographic Studies (CHS/CEH) with the support of its staff. The test at the site was completed within two days in November 2020. On the first day, an attempt was made to carry out the test as planned: a 3 x 1 m ditch, lined with a macro-perforated steel sheet, where the pumps are supposed to maintain a shallow pool of water (10 cm). However, the pumps failed to supply the flow rate needed for such size of the ditch and permeability. On the second day, after solving details of the performance and reducing the pool size to 1 x 1 m, the test was successful. A constant water level at the ditch was maintained at a flow rate of 520 l/min. This result, together with the geometry of the problem, solves the permeability of the earthfill.

The test failed to meet two conditions of the Vedernikov model: 2D flow and the presence of a horizontal fully-permeable boundary at the base. Once those deviations were corrected, the model yielded a permeability coefficient of $k \approx 0.7$ cm/s, reaching almost two orders of magnitude higher than that presumed then for the earthfill. Therefore, the doubts arisen on the dam safety during a rapid drawdown have been dispelled. Such coefficient of permeability seems to lie on the safety side, as the seepage might not flow in true laminar conditions.

DRAFTING THE NEW UIC NORMATIVE DOCUMENT UIC-IRS 70719-EARTHWORK AND TRACK BED LAYERS FOR RAILWAY LINES



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The International Union of Railways (UIC) has, among its documentation, a series of technical leaflets related to different elements and aspects of the railways, like leaflet 719 dedicated to earthworks and track bed for railway lines.

The publication of new standards and the advancement of knowledge have made it necessary to update these documents and their transformation into IRS (International Railway Solutions).

In order to update the leaflet 719 and turn it into the new IRS 70719: "Earthwork and track bed layers for railway lines – Design and construction principles", in May 2016, UIC set up an expert committee chaired by CEDEX Geotechnical Laboratory, and composed of representatives of the main railway managers in Europe and Asia.



Schematic railway cross section identifying the different zones.

One of the main goals of the new IRS document is to incorporate the European standards related to the objectives of the document, underlining the standards EN 16907 "Earthworks" and EN 1997 "Eurocode 7".

The document IRS 70719 is organized into seven chapters, highlighting the work done in Chapter 2, where the different terms used to define the different zones of a railway cross-section are unified, and Chapter 3, dedicated to the classification of soils and rocks to be used in the construction of new railway lines. This classification combines both the qualifying criteria set out in EN 16907 and the QSi quality classes frequently used in railway projects.



Award for excellence in standardization.

The leadership of the committee of experts exercised by CEDEX has made it possible to prepare a high-quality document, as has been recognized when it was awarded the prize for "Excellence in standardization", given by the UIC in its first edition, in which a total of 50 candidatures were presented.

IRS 70719: Earthworks and Track Bed Layers for Railway Lines
UIC document used for the railway projects by railway managers in both Europe and the rest of the world.

TECHNICAL ASSISTANCE TO DGC OF THE MINISTRY FOR TRANSPORTS, ON THE PATHOLOGIES OBSERVED IN BU-30 HIGHWAY



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The MITMA-DGC requested support from CEDEX in relation to some pathologies observed in a section of the Burgos ring road (BU-30). These pathologies were significantly affecting the normal operation of the highway. The section affected is located between the stations 12+625 and 13+000. In this zone, the highway runs in an embankment-type fill contained in one of its margins by a hybrid reinforced soil wall (up) and rock retaining wall (down).

The pathologies observed were manifested in the form of longitudinal cracks on the road pavement of the carriageway located next to the wall. The width of the cracks increases with time without showing a tendency to stabilize. This has caused road safety and traffic problems, and a higher road maintenance cost.

To diagnose the origin of the pathologies and propose the appropriate corrective measures, CEDEX has carried out various monitoring tasks of the infrastructure:

- Installation of mixed inclinometric and micrometric pipe in boreholes and monitoring of the corresponding deformations and movements.
- Measurement of relative movements with an invar extensometer.
- Control of topographic references with total station.



View of the hybrid wall (reinforced soil and rock) next to the BU-30 right carriageway.



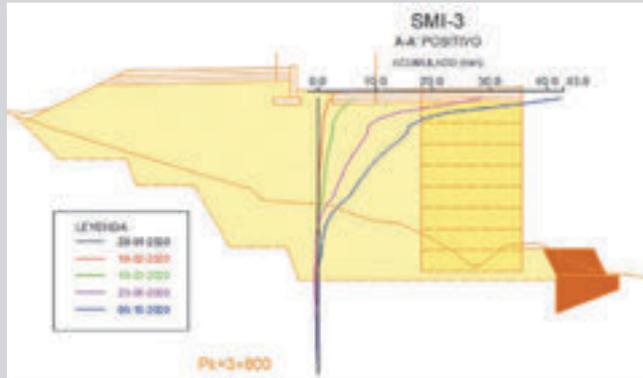
Cracks on the pavement of right carriageway.

- Laser scanning and comparison of the 3D point clouds obtained on different dates.

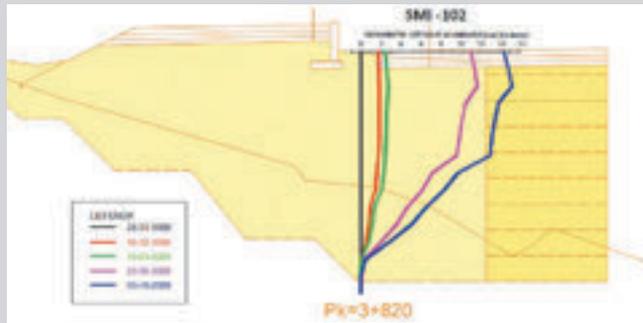
Precedent information, with geotechnical relevance from the construction phase, and the result of the new geotechnical surveys carried out for this purpose (4 boreholes and several dynamic penetrometers), have also been analyzed.

Based on the information provided by monitoring and the analysis of the available documentation, the possible causes of the observed pathology have been identified. For its correction, various alternatives have been proposed. The alternatives have been compared to each other using technical, economic and functional criteria, always bearing in mind the sustainability and resilience of the intervention.

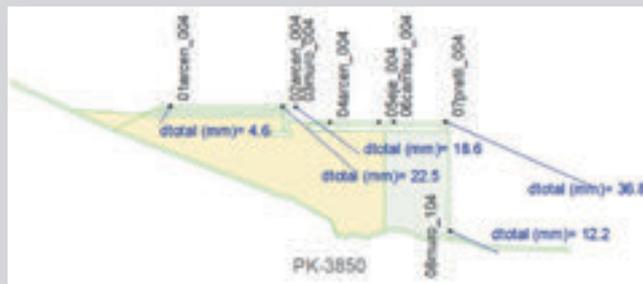
Finally, a report of conclusions has been drawn up in which the implementation of a corrective alternative, deemed as the optimal one, is recommended. Henceforth, technical support will continue to be provided during the corresponding works phase.



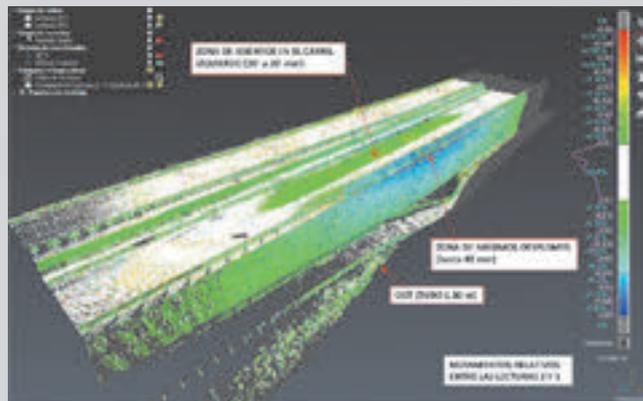
Horizontal movements in inclinometer.



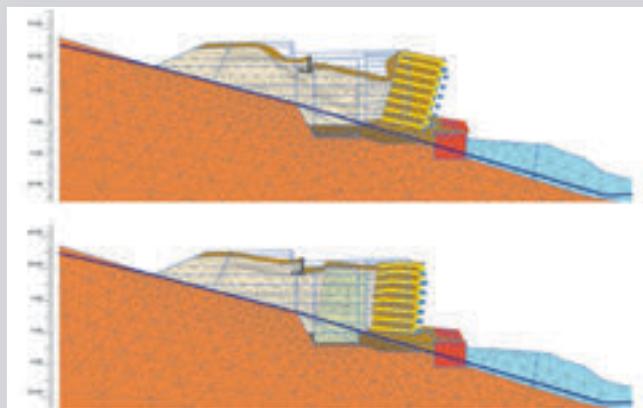
Vertical movements in micrometer.



Topographic control of movements.



Relative movements deduced by comparing 3D point clouds from the laser scanning.



Numerical models of finite elements for the technical analysis of the different action alternatives.





OUTSTANDING FACILITIES

FULL-SCALE ACCELERATED PAVEMENT TEST TRACK

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General view of full-scale accelerated pavement test track.

Full-scale accelerated pavement test track in Transport Research Centre of CEDEX is a worldwide reference facility in pavement testing. It's able to simulate in an accelerated way the heavy traffic effects on real sections of road.

APPLICATIONS

- Evaluation of structural response (strain and stress) related to the cumulative damage.
- Development and validation of pavement design model
- Analysis of pavement surface characteristics on new asphalt mixes.
- Studies of road markings.

Features

- Repeated and controlled application of loads by means of two vehicles simulating real traffic, with conventional tires and suspension.
- Two straight road sections with a length of 75 m joined by two curved road section with a radius of 25 m
- Vehicle speed range 0 to 60 km/h
- Applied load by gravity through a 13 t half axle (variable load range 5,5 to 7,5 t)
- Single or twin wheels
- Automatic transverse position change system on the move
- Application of 1.300.000 ESAL/year

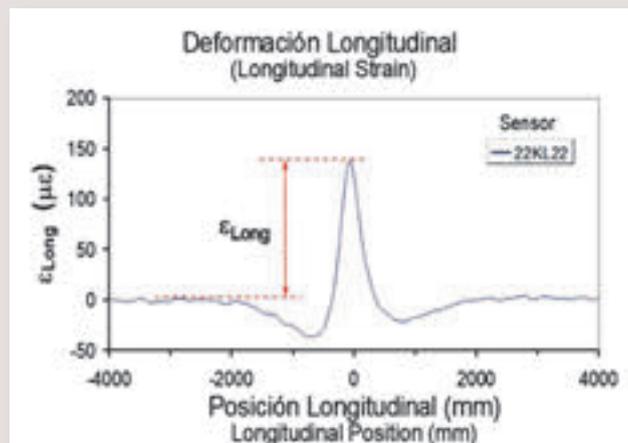


Chart of a sensor longitudinal strain inside the bituminous mixture related to loaded tyre position.

European projects which are used the test truck



In order to offer a better service, the facilities are being updated. To test ability expanding, technical prescriptions have already been specified so doubling of load axles, increasing machines speed and changing several damping parameters for simulating traffic specific features.

Trials on track are suited to test new materials and pavement sections before testing in real road sections and including in technical standard.

The latest study carried out consisted of studying the evolution of an AC22 mixture incorporating rubber powder into the production process as an additive (semi-wet process). At the same time, this mixture is compared to another AC22 mixture made incorporating rubber powder at the beginning (wet process).

Pavement response data are collected by more than 300 sensors: longitudinal strain gages, LVDTs, vertical pressure cell, temperature, humidity, suction.



LEACHING TEST LABORATORY OF THE TRANSPORT RESEARCH CENTRE

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In the framework of the Circular Economy, reuse and recycling receive a new impulse that demands the performance of environmental characterization studies. For this, prior to the reuse of a material, it is necessary to study its leaching behaviour by means of specific standardized tests.

The following leaching tests are carried out in this Laboratory of the Transport Studies Centre:

- Leaching behaviour test - Up-flow percolation test (under specified conditions), controlled by software and configured with the parameters of the EN 14405 and prEN 16637-3 standards.
- Compliance test for leaching of granular waste materials and sludges: One and two stage batch testing, according to the EN 12457 series of standards.
- Leaching behaviour test. Influence of pH on leaching with initial acid/base addition, according to EN 14429.

To complete the environmental characterization, it is necessary to analyze the eluates obtained by means of appropriate instrumental techniques that allow to evaluate the release of elements or substances potentially hazardous to the environment. The following eluate analysis is carried out at the Leaching Test Laboratory.



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 times and automatic measurement of up to 250 samples thanks to its SPS 4 Autosampler.

Materials tested in the laboratory.



AQUATIC ECOLOGY EQUIPMENT

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Sampling of ichthyological fauna with portable electric fishing equipment in the Miño River for the Albufeira Project (2020).

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.

Fieldwork and sampling equipment

Platform for obtaining sediment cores and samples with piston and percussion system (Model UWITEC Piston corer), and core extrusion and lamination system.

Multiparameter Sonde YSI Model EXO2 with 100 m cable and GPS, and sensors for depth, temperature, conductivity, pH & ORP, dissolved oxygen, turbidity, total algae (chlorophyll) and phycocyanin /phycoerythrin.

Electric fishing equipment 1,3 kW, 300/500 W and 940 V pulsed, with engine Honda 4T GXV50 6700 rpm, and accessories for biometric studies.

TELEDYNE ISCO Model 6712 Full-Size portable automatic sampler with connection of multi-parameter sondes, level sensors and remote communication via bidirectional GSM.

Outboard boat Whaly 500R Professional with Mercury F60 ELPT EFI (4T) motor, GPS navigator system and echo-sounder-plotter Garmin, and a manual operated winch for different samples acquisition systems (hydrographic and integrating bottles, dredgers, gravity cores, ...) for limnological work in reservoirs, lakes and estuaries.

HYDRAULICS LABORATORY

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General view of Hall I (left) and Hall II (right).

The Laboratory facilities are intended to test with physical model studies of hydraulic structures and fluvial studies in the field of continental waters, in addition to environmental hydraulics studies. Complementary to the specialized technical assistance work, several lines of applied research are being developed in fields of interest to Spanish hydraulic engineering.



Hall I, designed by Miguel Fisac, is has concrete beams of 22 m of length with a characteristic bone shape that guarantee a natural lighting of great uniformity and that have a special architectural value. Hall II, designed by José Antonio Torroja, has a roof with a wide reticulated metallic structure, the largest models are located there.

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 0.25x0.40 m (of 6.10 and 7.50 m length) and one of 0.40x0.60 m (12.00 m length); and two horizontal channels: one of 1.00x1.00 m (50 m length) and one of 1.50x1.50 m (100 length). The maximum flows vary between 25 and 500 l/s.



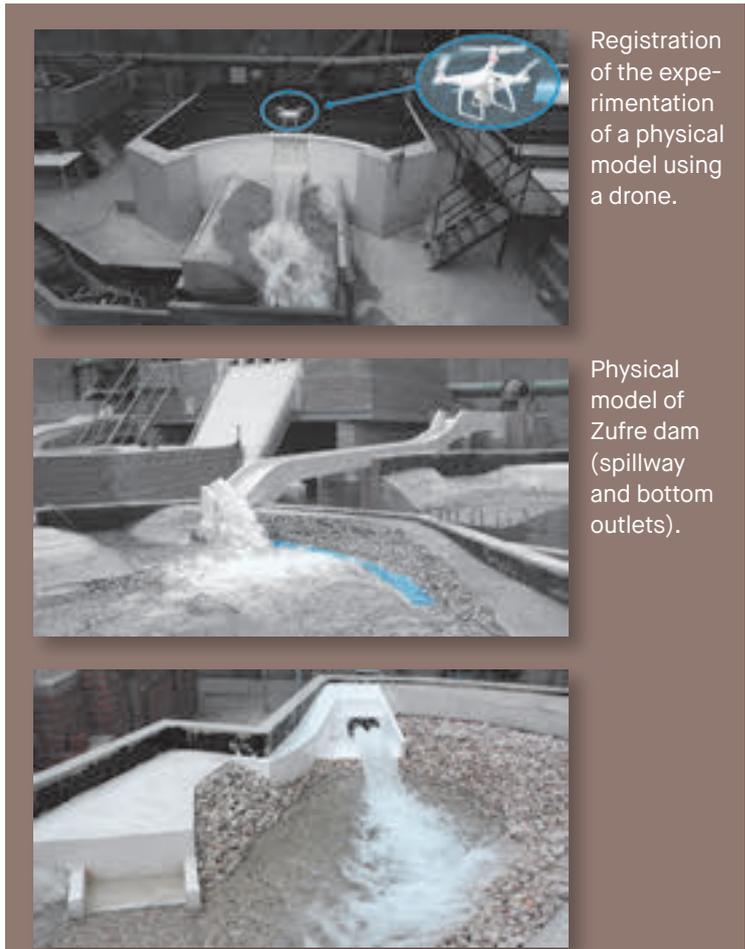
R&D and innovation projects in the Hydraulics Laboratory.

5. Installation for the experimentation on stepped spillways, forced aeration spillways and stilling basin optimization.
6. Experimentation on wedge-shaped protections for rockfill dams.
7. High tanks for bottom outlet testing.
8. Installation for special spillways testing (siphons, labyrinth, piano key ...).

Equipment and instrumentation

The Hydraulics Laboratory has all the necessary equipment for physical model studies as well as to register the hydraulic variables. The following equipment can be highlighted, among others:

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.



Registration of the experimentation of a physical model using a drone.

Physical model of Zufre dam (spillway and bottom outlets).



Physical model of the Canal del Enlace Directo (Huelva).

- 3. 3D scanner (shared with the Centre for Studies on Ports and Coasts of CEDEX).
- 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.

- 9. Use of 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 1/10 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.

- 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).



3D laser printer fabrication of a Howell-Bunger valve (Canal del Enlace Directo model).

WATER QUALITY LABORATORY

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Water Quality General Laboratory.

Analysis of chemical compounds in water and other water matrices.

- Ion chromatography with titrator and UV/VIS detectors, conductivitymeters 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.



Metal Analysis laboratory

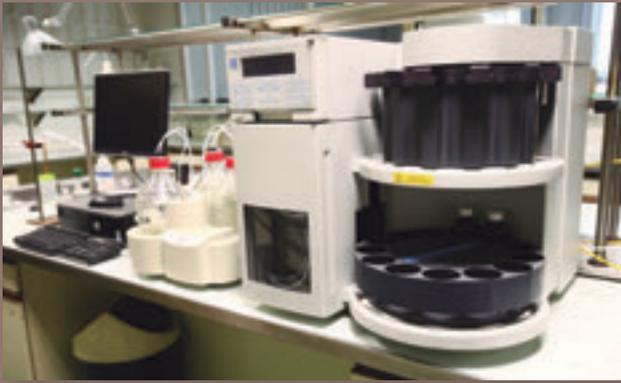
- Continuous Flow Injection Mercury System (FIMS) and Atomic Absorption Spectroscopy (AAS) for the analysis of Hg and metals in water.
- Atomic emission spectrometer with ultrasonic nebulizer that uses the Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) analytical technique. Multi-elemental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





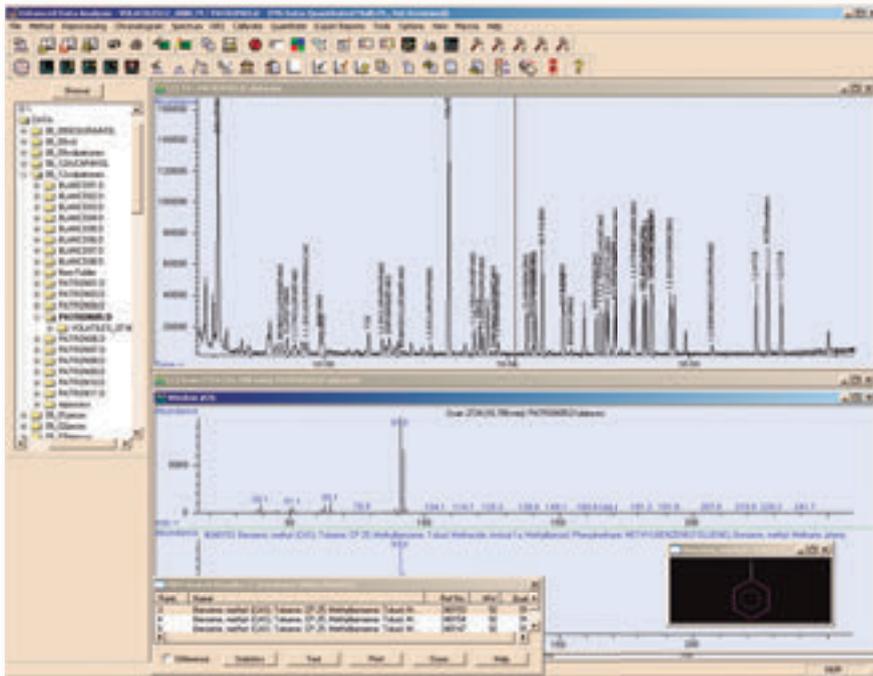
- Power-Prep system of automated fluids for the extraction and purification of samples (dioxins, PCBs, pesticides, PAHs, etc.).
- High resolution liquid chromatograph with high resolution triple quadrupole mass detector and E-quan system for direct introduction of liquid sample (HPLC/MS/MS). It is used 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 fine-tuning several methodologies that have served to participate in numerous works.
- High pressure liquid chromatograph with fluorescence detectors and Diode Array and Pickering post column derivatization system (HPLC). Analysis of pigments, polycyclic hydrocarbons, LAS, carbamates among others.
- Gas chromatograph coupled to a purge and trap quadrupole mass spectrometer (P&T/GC/MS). Analysis of volatile and semi-volatile compounds.
- High resolution mass spectrometer with Orbitrap technology. The spectrometer is coupled to:
 - 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 (Headspace) for volatiles analysis and solid phase microextraction (SPME).

This high-tech equipment puts the Laboratory at the forefront for the detection of pollutants and substances included in the research control program defined in the Royal Decree that establishes the criteria for monitoring and evaluating the state of surface waters and environmental quality standards and in the Water Framework Directive.

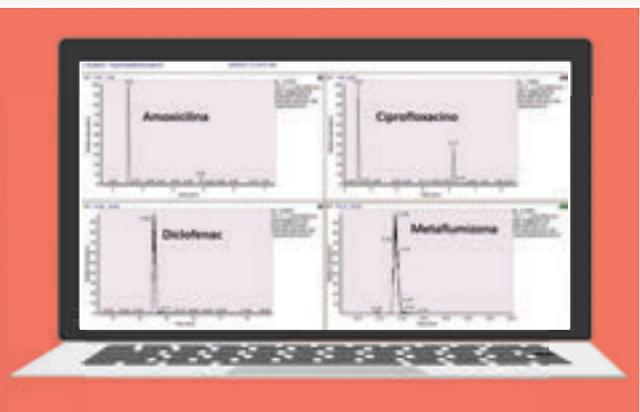
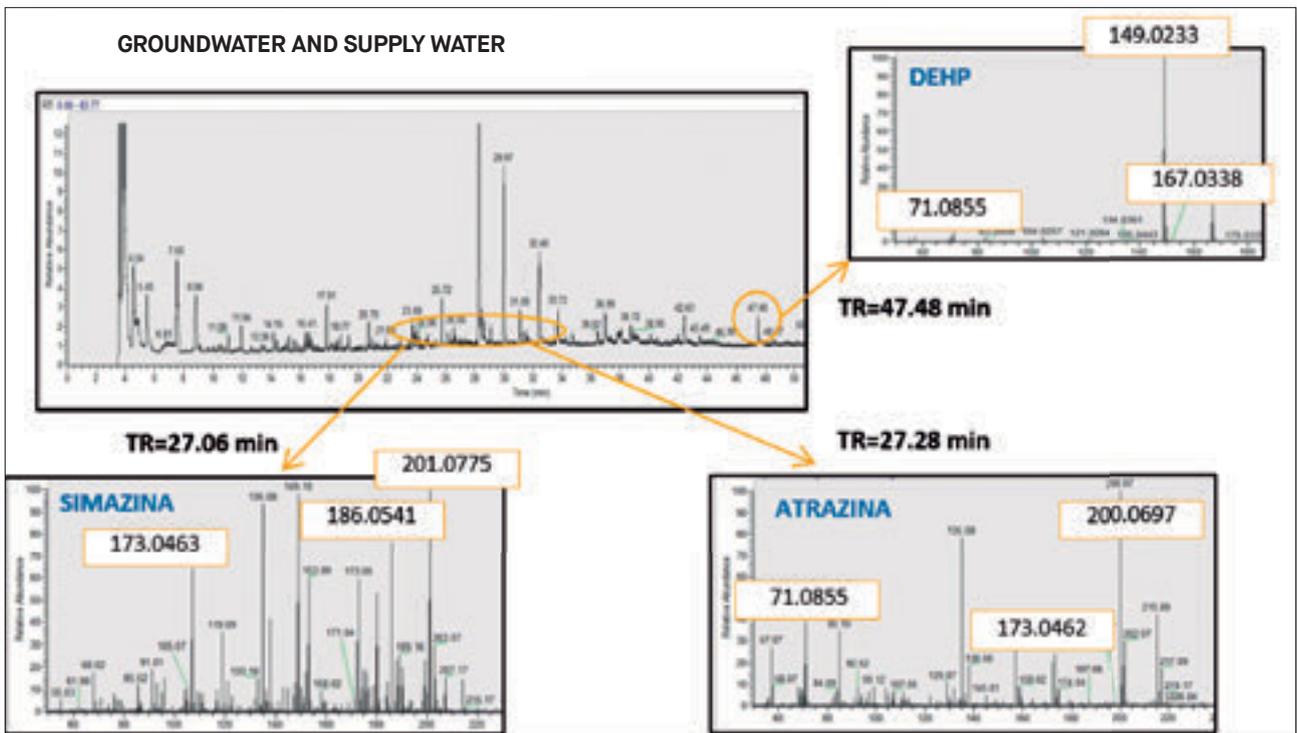
The equipment can work in high resolution (120,000 m/z) to obtain exact masses with an absolute mass error of 0.002 Da (5ppm), allowing the identification and quantification of known compounds at trace levels and the presence of unknown compounds in the sample. With this equipment, different emerging 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.

Some studies carried out



Analysis of volatile compounds in aqueous samples by PT-GC / MS.

Chromatographic profile of groundwater and supply water samples. Identification of pesticide residues from the exact masses of the fragments observed using the high-resolution mass spectrometer with Orbitrap technology.



COMPUTING CENTRE

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NetApp FAS 2552 array.

The Computing Centre contains the Information Technology infrastructure used by the Centre for Hydrographic Studies for the tasks assigned to it.



Asus ESC4000G2: 160 GB RAM, 16.94 TB Storage

Nvidia GeForce Titan GPU
Nvidia GeForce 750 Ti GPU
Nvidia GeForce 750 Ti GPU

It has a NetApp FAS2552 storage array with 165 TB actual physical capacity and 700 TB deduplication. It is a device connected via fibre channel (high speed, lossless fibre optic network to handle remote and distributed storage and backup) to a virtualization blade chassis with two servers with 64 GB RAM each.



Supermicro 4028GR-TR: 256 GB RAM, 3.48 TB Storage

Nvidia GeForce 1080 GTX GPU
Nvidia GeForce 1080 GTX GPU
Nvidia GeForce Titan GPU

The storage cabinet also provides network file storage with CIFS (Common Internet File System) and NFS (Network File System) protocols, network file systems for Windows and Linux, to users of the Centre for Hydrographic Studies.



Supermicro 4029GP-TRT: 288 GB RAM, 4.36 TB Storage

Nvidia Tesla V100 PCIe 32GB GPU
Nvidia Tesla V100 PCIe 32GB GPU
Nvidia Quadro P5000 GPU

In turn, there is a Quantum i500 tape array with capacity for 86 tapes, expandable to 130 LTO-7 type tapes (each with a capacity of 13 TB) to perform backup tasks, through the same fibre channel network.

Likewise, for the usual computing works of the Centre, several HPC (high performance computing) servers are used based on GPU computing (graphic processing units), of CUDA technology (Unified Architecture for Computing Devices).

These computers have a high computing capacity, with memory between 160GB RAM the smallest and 288 GB RAM the most advanced.

In addition to containing a dual processor with 16 cores each, its most representative feature is the possibility of containing between 8 and 10 cards with GPUs computing. Currently the last server acquired uses two V100 NVidia cards with Tensor Core technology with 5. 120 CUDA cores and 640 Tensor cores with an internal communication bandwidth of 900 GB / s that allows to process models of several million particles with SPH (Smoothed-Particle Hydrodynamics - computational method used to simulate the dynamics of continuous media). Next, we detail the equipment available for massive computing.

This infrastructure is supported on a communications network based on two 10 G Ethernet switches that connect these servers to the core network of the Centre for Hydrographic Studies and a fibre channel network with capacity up to 16 Gbps for data transmission with the disk storage network and with the file backup system of the Centre for Hydrographic Studies.



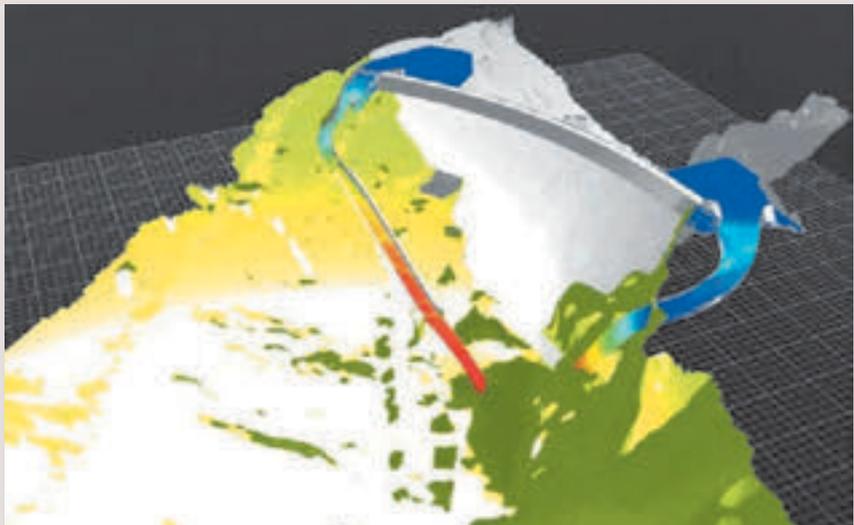
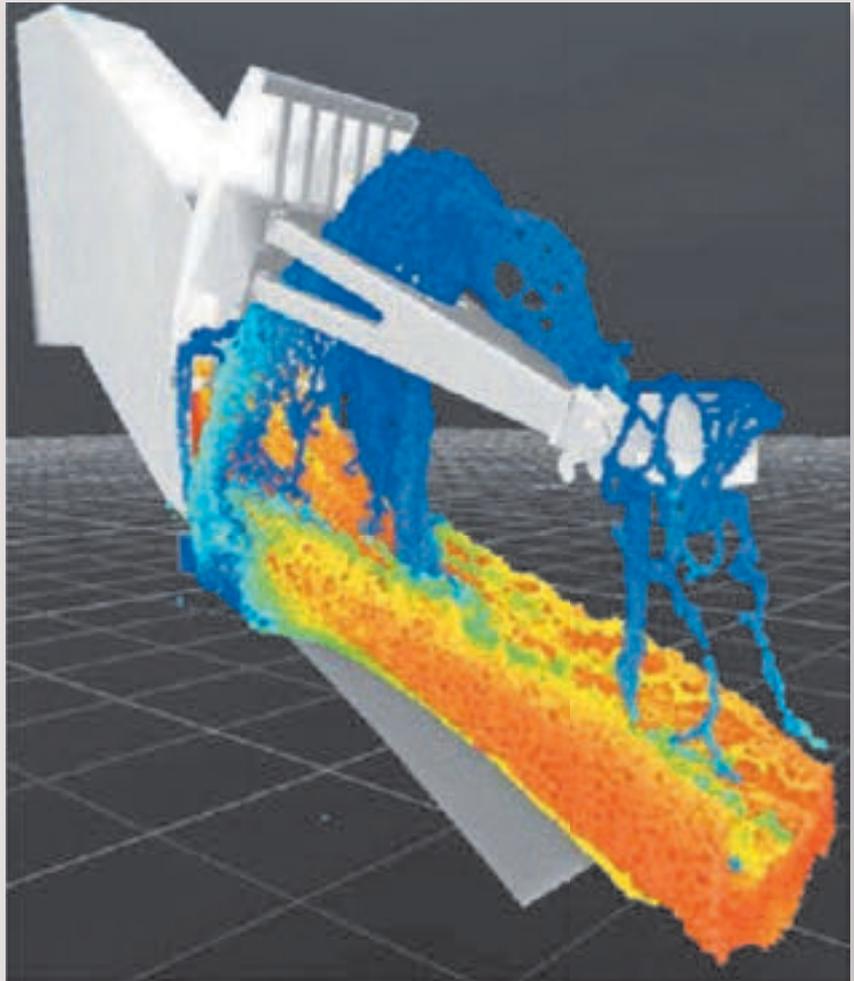
Computing Centre.

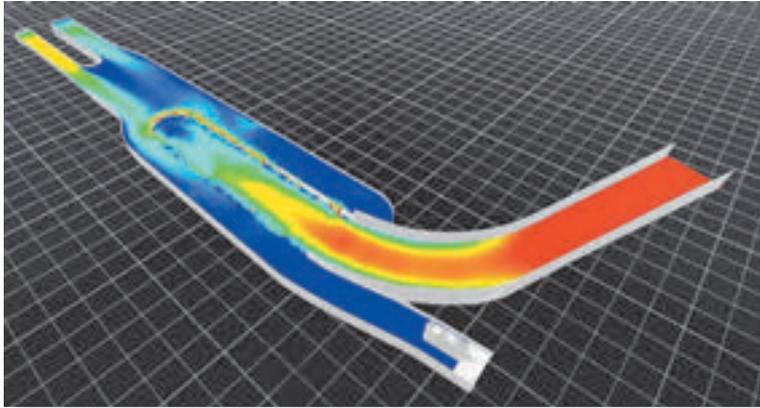
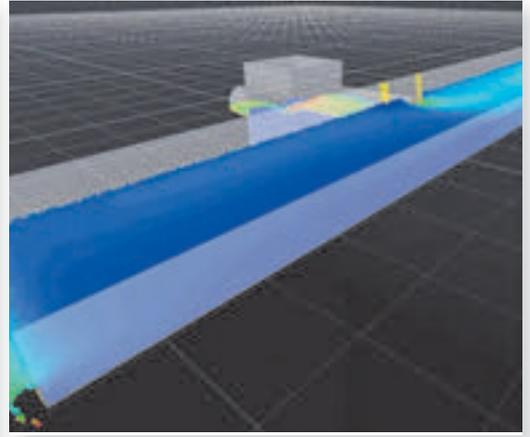
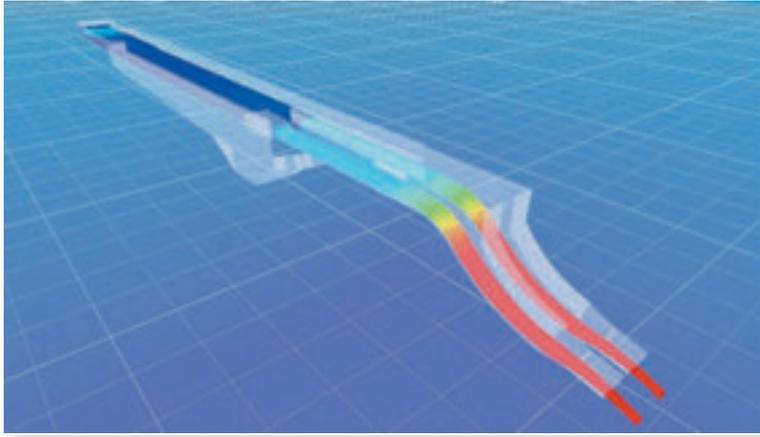
VIRTUAL REALITY ROOM

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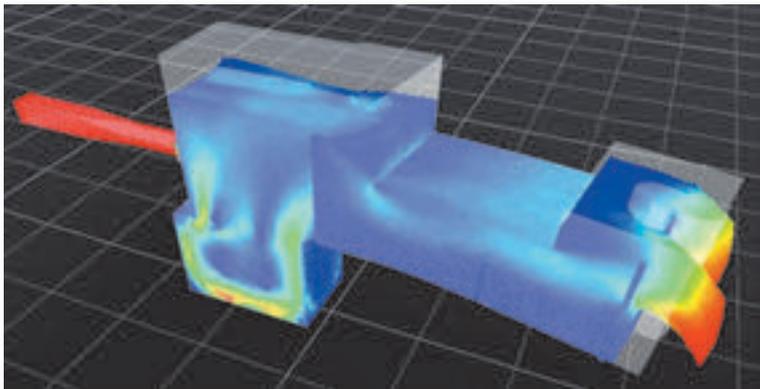
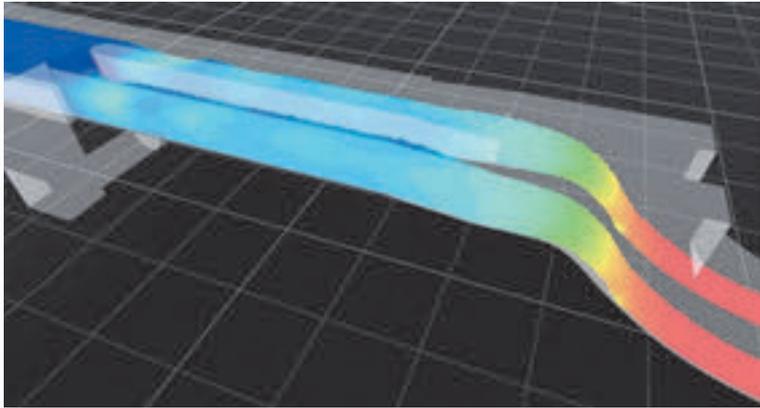
In order to visualize numerical 3D models by stereoscopic techniques, the Centre for Hydrographic Studies has a virtual reality room to ease 3D model analysis and rendering.

The room has two technological mechanisms to produce 3D stereoscopic vision, both passive and active systems.





Hydraulic structure modelling with SPH.



EUROBALISE LABORATORY

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Calibration test.

The Eurobalise Laboratory of the Railway Interoperability Laboratory (LIF), of CEDEX, has been the first European laboratory accredited for the execution of the Eurobalises 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 related to the Control, Command and Signalling subsystem.



General view of the LIF's Eurobalise Laboratory.

The laboratory also participates in special studies in the scope of the Eurobalise, and over the last few years has been taking part in European

projects related to the use of Global Navigation Satellite Systems (GNSS) for train location in ERTMS.

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

- ✓ Subset-085 'Test Specifications for Eurobalise FFFIS': Eurobalise and Antenna/BTM tests.
- ✓ Subset-103 'Test Specification for Euroloop'.
- ✓ Subset-116 'Eurobalise On-board Equipment, Susceptibility Test Specification'.

ERTMS TRAFFIC SIMULATION LABORATORY

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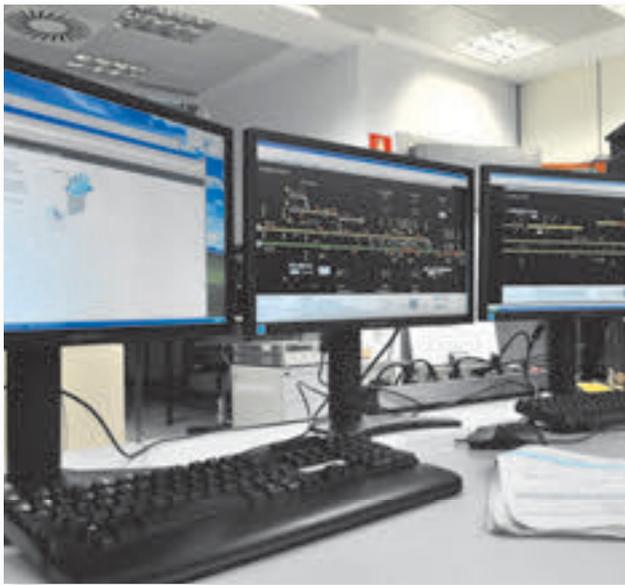
Laboratory view.

The functional tests of ERTMS are carried out in the ERTMS Traffic Simulation Laboratory of the Railway Interoperability Laboratory (LIF), of CEDEX, being the exchange of information between track and train identical to what happens in a real environment. By using this tool, the complete debugging of the entire system can be achieved before its deployment in the real line, with the consequent saving of time and money.

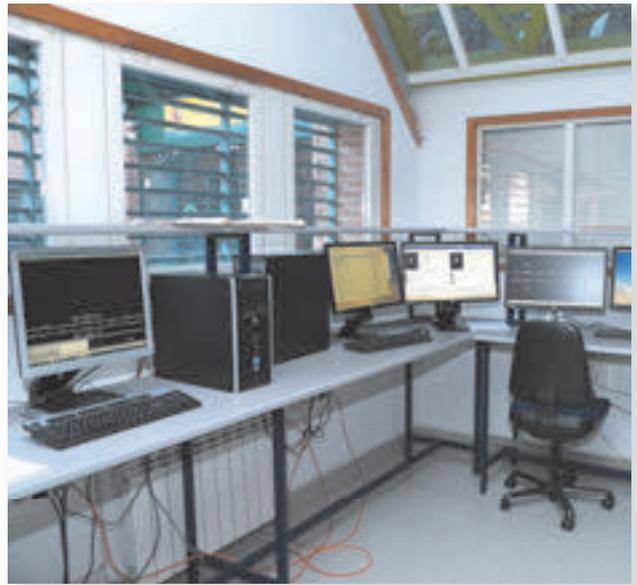
The ERTMS (European Rail Traffic Management System) Traffic Simulation Laboratory has been the first European one to carry out tests of real ERTMS L1 and L2 lines in the laboratory.

In order to support Adif and Renfe Operadora in the process of commissioning new lines and trains equipped with the ERTMS, the Traffic Simulation Laboratory provides the possibility of testing 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 L1 and RBC -Radio Block Center- in L2) and their con-



Routes setting.

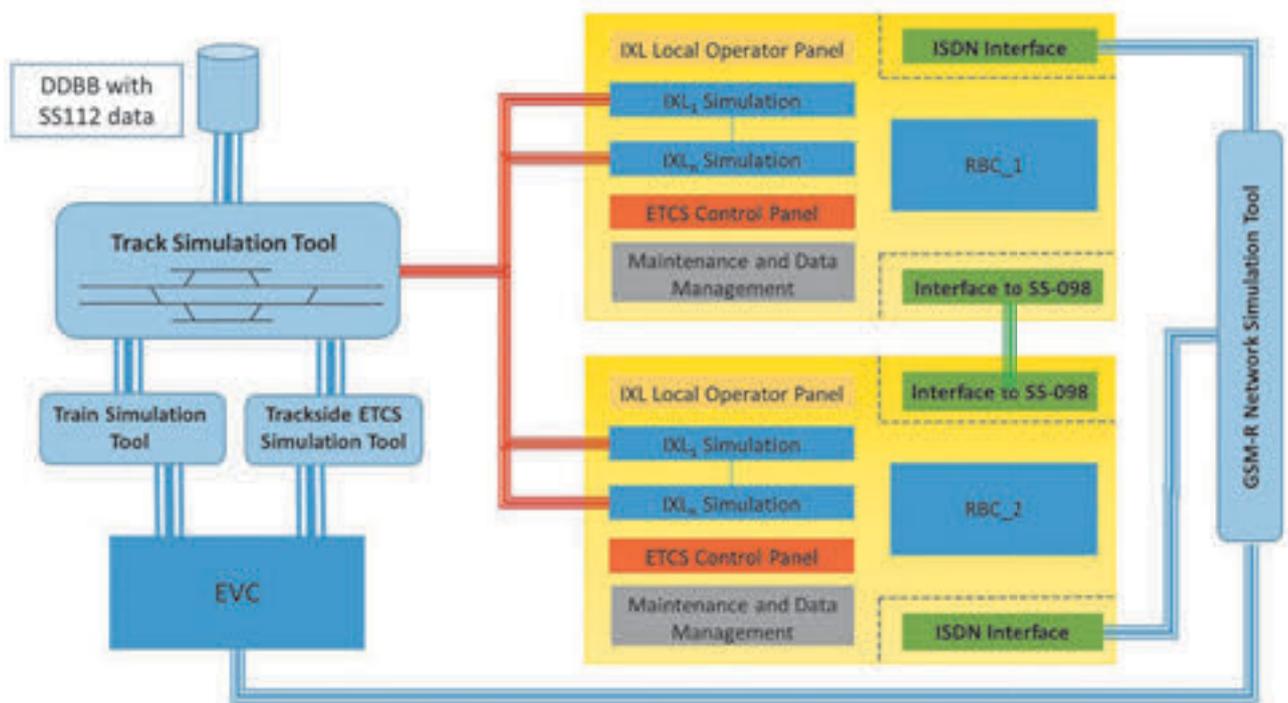


Traffic Simulation Lab.

nection thereof to the Traffic Simulator that simulates the track topology, detours, track circuits and signals of the line.

In parallel, the on-board ERTMS or EVC (European Vital Computer) equipment is integrated and connected to the train movement simulator of the laboratory.

The Traffic Simulation Laboratory has tested the main Spanish lines equipped with ERTMS (Madrid-Valencia, Valladolid-Burgos-León, Olmedo-Zamora, Madrid Commuter Lines, Barcelona Commuter Lines, etc.), as well as lines from other countries (Saudi Arabia, Belgium or Senegal).



Scheme of the ERTMS Traffic Simulation.

EUROCAB LABORATORY

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Eurocab lab.

The Eurocab Laboratory of the Railway Interoperability Laboratory (LIF), of CEDEX, has been the first European laboratory to carry out the execution of certification tests of ERTMS on-board equipment or EVC. In 2020 a project for the automatization of test execution and test evaluation has been performed with the aim of reducing the testing time.

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 on-board ERTMS or EVC equipment (European Vital Computer) of all European manufacturers.

Since 2005, the 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 relative to the ERTMS Control, Command and Signalling subsystem.

All European ERTMS manufacturers have passed by the Eurocab laboratory: Alstom, Ansaldo, Bombardier, Caf, Hitachi and Siemens, so the Laboratory has become a reference, accredited by ENAC according to standard 17025 in 2012.



Remote control of DMI robot.

MARITIME EXPERIMENTATION LAB: EXPERIMENTAL HALL

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Vista general de la nave de ensayos.

The Center for Ports and Coastal Studies of CEDEX has a Test Experimental Hall with large facilities for conducting tests on a reduced-scale physical model.

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 & 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 currents 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 its 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".

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 2020, the Multidirectional Wave Tank was renovated, providing it with a higher capacity of the multidirectional wave generation system, a new filling/emptying and filtering systems, as well as the implementation of a new software that allows to have a better reproduction at scale of the phenomena related to wave propagation and wave/structure interaction.

In these facilities, environmental tests are also carried out, such as studies of effluents from desalination plants and water 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 port facilities plant 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 also has a set of elevated walkways for overhead observation.

SHIPS MANEUVERING SIMULATOR OF CEDEX

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Overview of the main bridge of the CEDEX simulator.

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 is piloted by nautical personnel.

Types of feasible studies

- Port access and exit maneuvers and ship docking.
- General navigation.
- Emergency manoeuvres
- 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.
- Off shore studies.

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.

This facility will replace another simulator put into operation at CEDEX in 2002. Since its installation at the Center for Port and Coastal Studies in 2002, ship maneuvering studies have been carried out in almost all the ports of the Spanish Port System, the most significant being the following:

- Design of new port developments: outer ports of Ferrol, Coruña, Gijón, Melilla, Valencia (North basin), Escombreras, etc.
- Expansion or change of uses of its facilities: ports of Tarifa, Motril, Alicante, Castellón, Barcelona, Mahón, Las Palmas, Palma de Mallorca, etc.; and some from outside Spain: Buenaventura and Cartagena de Indias (Colombia).
- Analysis of the behavior of anchored vessels: Bahía de 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 Detroit Jet in Tarifa, stranding of the Cajonero Agronauta on the coast of Malaga, etc.
- Wind turbine towing studies: R+D+i CAPEMA and R+D+i TELWIND projects.

Main Bridge

Provided with:

- Steering and control elements: rudder, machine command telegraph, control of thrusters and anchors, roop and mooring control, 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.
- ECDIS electronic navigation chart
- High resolution panoramic outside view image of 360° horizontal amplitude: 9 channels, cylindrical surround screen with 270° horizontal amplitude and 15m diameter.
- Projection system consisting of 7 high resolution laser projectors and 2x55" monitor inside the bridge to complete 360° outside view.
- Point of view control: view from the bridge, from the ailerons, looking aft, a "bird's eye view", binocular, dron view.

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
- ECDIS electronic navigation chart
- Panoramic and high resolution exterior image: 3 flat screens of 120° 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", binocular and dron view.
- Instrumentation screen: conventional and azimuth engine telegraph, rudder control, GPS, etc.

Four Auxiliary Bridges (microsimulators)

Equipped with: digital instrumentation, conventional and azimuth telegraph, rudder control, GPS, VHF communication and an outside 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

- 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.

LABORATORY OF ISOTOPE APPLICATIONS

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Distillation cells for water samples after electrolytic concentration and before the measurement of the activity of tritium by scintillation counting.

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.

The Laboratory of Isotope Applications has set up a group of specific techniques for water sample preparation and the measurement of radioactivity at very low levels and mass spectrometry to be applied in environmental radioactivity surveillance and isotope hydrology

The following analytical techniques are available in environmental radioactivity surveillance:

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.
5. Liquid scintillation spectrometry, for the measurement of the activity of tritium through direct and electrolytic concentration.

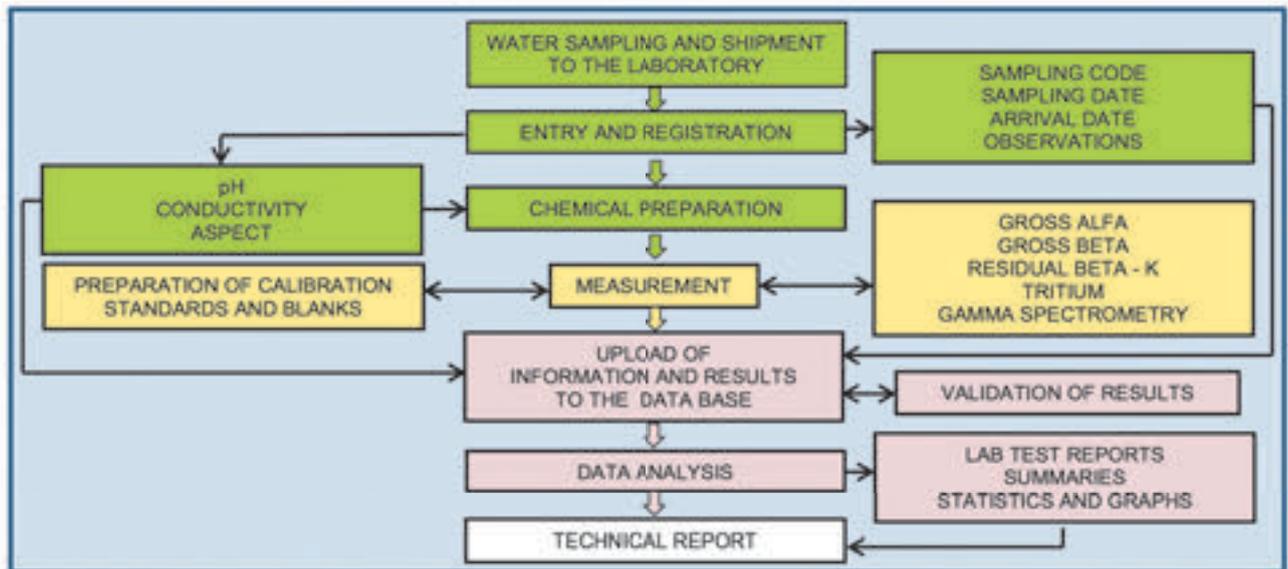


Chart for sample preparation, laboratory essay and reporting for radioactivity surveillance of the aquatic environment.

- 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

6. Ionization chamber, for the continuous measurement of radon-222 in air and water.

The analytical techniques available in isotope hydrology are directed to the determination of the isotopic relationships of light elements for tracing and the measurement of in water samples for dating by the following methods:

1. Laser spectrometry and mass spectrometry for deuterium and oxygen-18.
2. Liquid scintillation spectrometry, for the measurement of tritium activity after distillation and electrolyte concentration.

These methods are applied to trace water provenance and solute transport processes of interest in hydrology and geochemistry. Dating techniques to estimate the times for the renewal of water resources and the transport of contaminants in groundwater bodies are complemented with the use of geochemical models for carbon-14 in Dissolved Inorganic Carbon (DIC).

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 by CEDEX in studies of isotopic hydrology in Spain. These data are increasingly used in the calibration of general circulation models of the atmosphere, studies of climate change and ecosystems functioning, and food security.



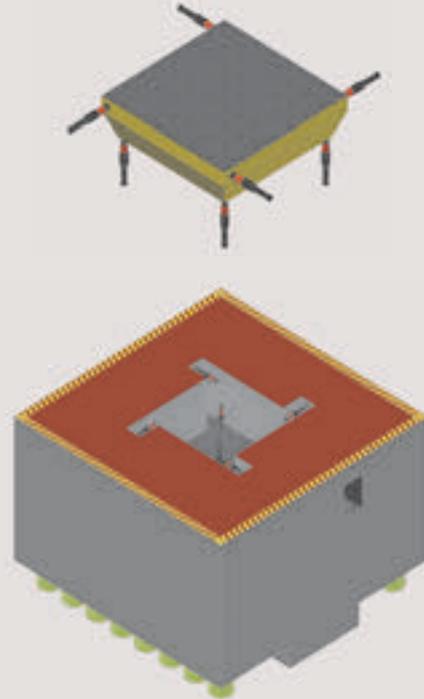
Pluviometric station of REVIP "El Retiro (Madrid)". Picture: Javier Rodríguez Arévalo

SEISMIC SIMULATOR WITH SIX DEGREES OF FREEDOM

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Vibration and shock test on a BPE-PAR Stabilizer.



Representation of the Seismic Simulator installation. Reaction mass and table with actuators.

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

Within the field of seismic engineering, it's of overriding importance to carry out experimental studies of the behaviour of structural elements and 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 are 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's noteworthy 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 and Civil Protection; and vibration and crash tests of railway equipment.

- Seismic structural
- Modal analysis for determination frequency
- Frequency sweep
- Random signal for fatigue of railway material

TESTS PERFORMED

LABORATORY OF CONCRETE DURABILITY

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General view of the permeability laboratory.



Corrosimeter: measurements *in situ*.

- **Water penetration test:**
Two sides of 10 specimens tested simultaneously.
100 to 200 mm diameter and up to 300 mm height
- **Water permeability test.**
8 positions. 150 mm diameter specimen, maximum working pressure 15 bars
- **High-pressure water permeability equipment,**
with 54,74 x 100 mm Hoek cell
- **GECOR-8 Corrosimeter:**
resistivity and half-cell potential with Cu/SO₄Cu electrode. Corrosion Intensity in aerial structures with modulated confinement

Permeability control of concrete is mandatory to ensure good behavior in aggressive environments, according to Spanish Instruction EHE-08.

The laboratory has a custom-made water penetration equipment, with the possibility of carrying out simultaneous tests on both faces of the concrete specimen. The equipment is unique in Spain allowing simultaneous test of the permeability in the cover and the inner part of concrete cores, which makes possible to know the effect of problems related to the placement of concrete on its durability.

Plus, the laboratory has a high-pressure Hoek cell equipment that provides direct water permeability results in high strength concrete specimens.

In order to evaluate the corrosion state of reinforcement in structures on site, a Corrosimeter GECOR-8 is used. This equipment provides three useful electric measurements. Concrete resistivity shows the concrete resistance to work as an electrolyte if a corrosion process takes place in reinforcement. Half cell potential shows the presence of corrosion anodes in the bars. Finally, corrosion intensity measurement has a special value because it confirms the existence of active corrosion and also quantifies its importance.

GECOR provides full information about corrosion process and is able to detect its presence when concrete damages aren't yet visible. Nevertheless, this equipment needs to have an accessible steel bar, and good electrical connections with concrete, which slows down field measurements.

As a complementary equipment, CEDEX has a Wenner 4 probe tester, which provides fast surface resistivity measurements through structure resistivity mapping. This quick evaluation allows to differentiate special corrosion risk areas, to be later evaluated with the corrosionimeter.

CEDEX-DRONE OPERATOR

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Photogrammetric restitution work carried out by CEDEX.

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

CEDEX has developed the strategy of using drones to support field works. To do so, it's set up 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 different working 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's centres and laboratories have an agent in the Drone Operator task force, 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, small size and very handy; and another bigger and able to carry light loads like different sensors for each operation. CEDEX Drone Operator is enabled for recording video and taking 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 is 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



Phantom 4 (Quadcopter)

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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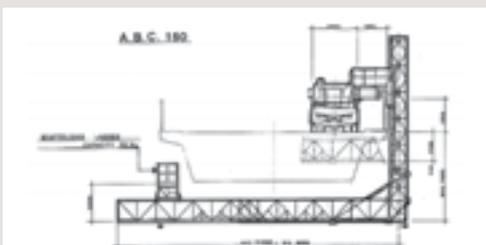
Inspection of the Zuazo bridge (Cádiz).

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

As a part of maintenance works, structural inspection and monitoring have 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.

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



- Total weight: 23.000 Kp (vehicle+platform)
- Maximum unfold length: 15,00 m
- Platform width: 1,50 m
- Occupied line road width: 2,50 m
- Deck depth: 1,70-6,50 m
- Time for unfolding: 6 minutes
- Passing piles without folding
- Maximum railing deck height: 1,80 m
- Maximum bridge sidewalk wide: 1,80 m

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.

PHOTOMETRY LABORATORY

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Control unit and sample holder.



View of the retroreflectometer and goniometer.

The Photometric System, located at the Photometry Laboratory, is for evaluating the behavior of the photometric characteristics of all retroreflective materials used in road equipment.

This system consists of:

- **Retroreflectometer;**
- **Goniometer; and**
- **Display, control and data processing console.**

- The range of the observation angles, α , goes from $6'$ (0.1°) to 2.0° , due to the movement of the photometer head.
- All the entrance angles, β , defined in the regulations can be achieved, around the vertical and horizontal axes, in clockwise and counter-clockwise direction.

In this laboratory, angularities or geometries that are impossible to achieve with current portable equipment, can be reproduced with this system, and due to this, a minimum distance of 15 meters is necessary between the two main components of the system, retroreflectometer and goniometer. The results of the measurements obtained are absolute, since the use of standards isn't necessary. Photometric system allows working in the measuring range of:

- Coefficient of Luminous Intensity, RI: 0.1 mcd / lx to 199,900 mcd / lx
- Coefficient of Retroreflection, RA: 0.01 cd / (lx. m²) to 19,990 cd / (lx. m²)

The photometry equipment meets all the specifications defined by the International Commission on Illumination (CIE) to perform photometric measurements on retroreflective materials used in road signs. All the geometries defined in National and European Standards can be reproduced in the Photometry Laboratory for all classes of retroreflective materials obtained by the different technologies, such as:

- Retroreflective sheetings with glass microbeads, and
- Microprismatic polymeric retroreflecting sheetings.

Measurements must be made in total darkness, therefore all the walls, ceiling and floor are matte black. Accessories or devices: The acquisition of some devices has increased the performance of the photometry system, enabling it to carry out measurements with new geometries incorporated in the Standards, both National and European.

- Nonius: allows the selection of the epsilon rotation angle (ϵ).
- Illuminance meter: allows verifying the luminous flux emitted by the light source, as well as its uniformity in the 250 mm diameter illumination area.

CEDEX TRACK BOX (CTB)

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General view of the test facility.

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.

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.

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

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

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.

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 |



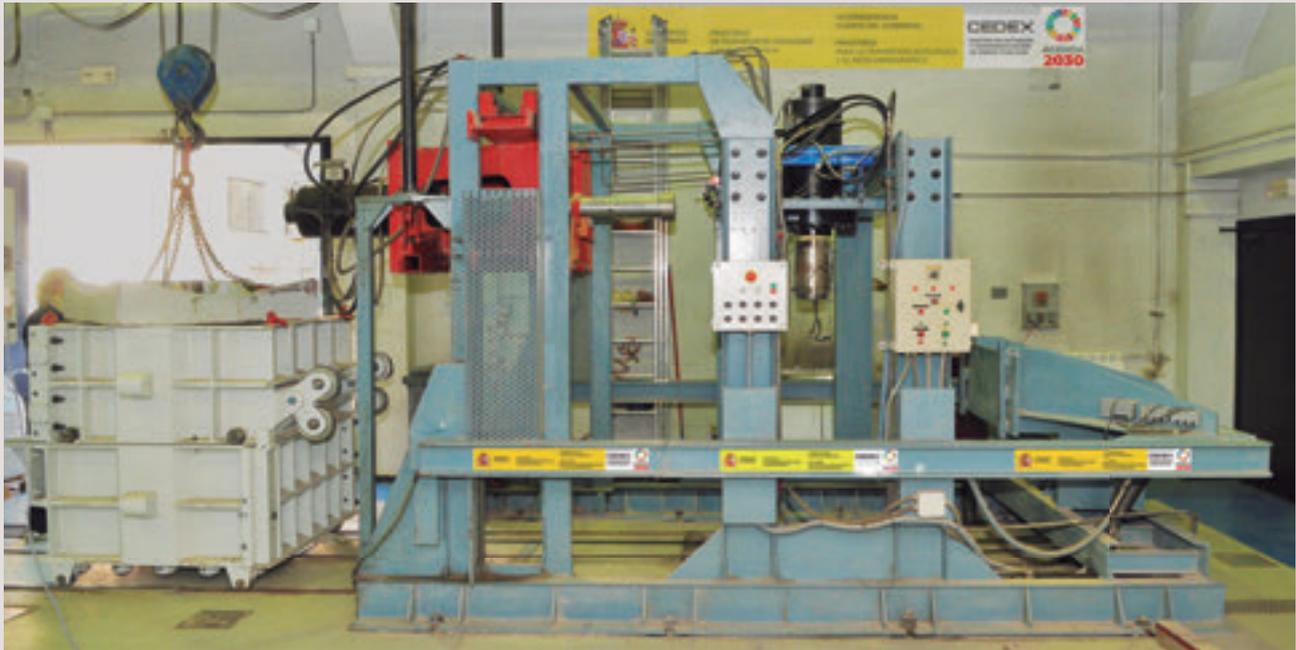
Detail of three pairs of servo-hydraulic actuators.



Fatigue test on slab track.

DIRECT SHEAR BOX FOR COARSE GRANULAR MATERIALS

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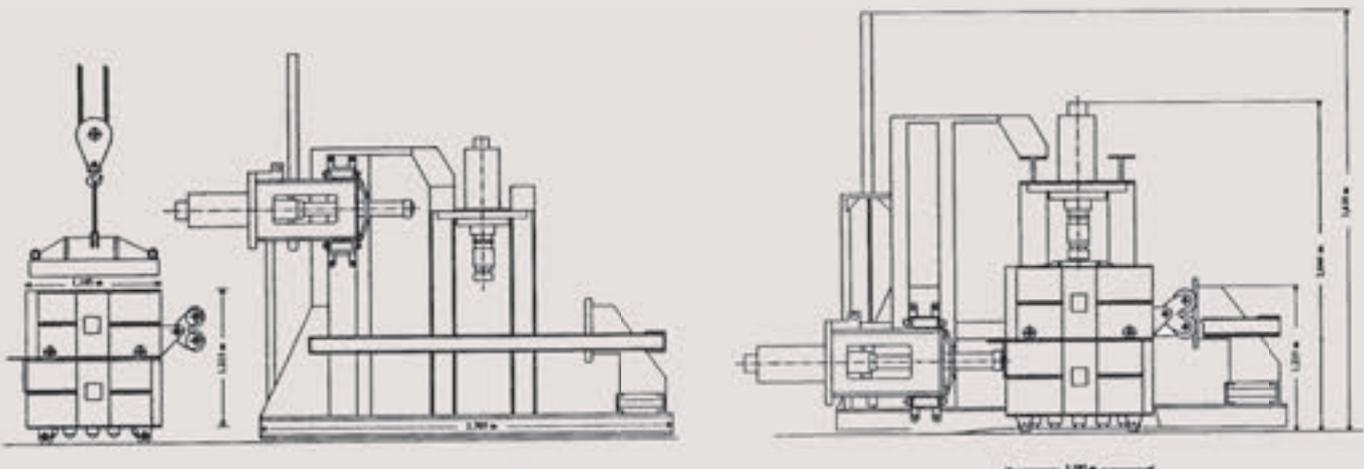


Lateral view of the Large Shear Box at CEDEX Geotechnical Laboratory.

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).

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.



Schematic diagram of Large Shear Box

Main specifications

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

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.

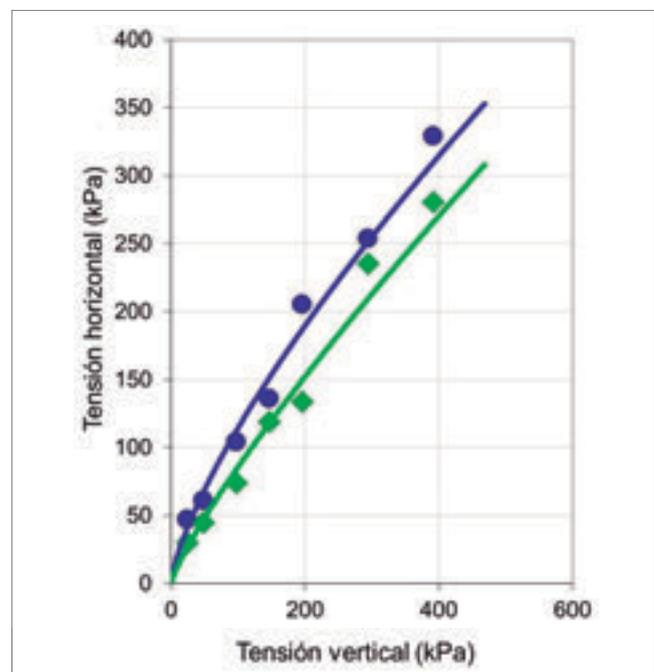
The sample is placed in the shear-box by vertical discharge. Some compaction can be made by using the vertical actuator or a small jackhammer compactor.

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-Ballast shear strength.



Sample placed by vertical discharge.



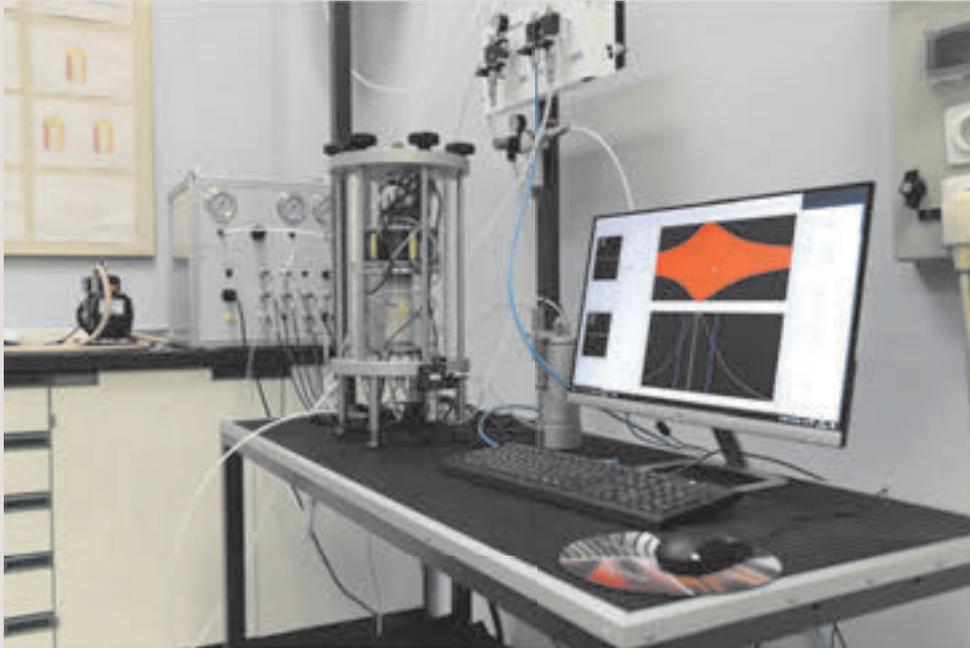
Example of results obtained.

- 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

DIFFERENT PERFORMED TESTS

RESONANT COLUMN AND SHEAR TORSIONAL DEVICE

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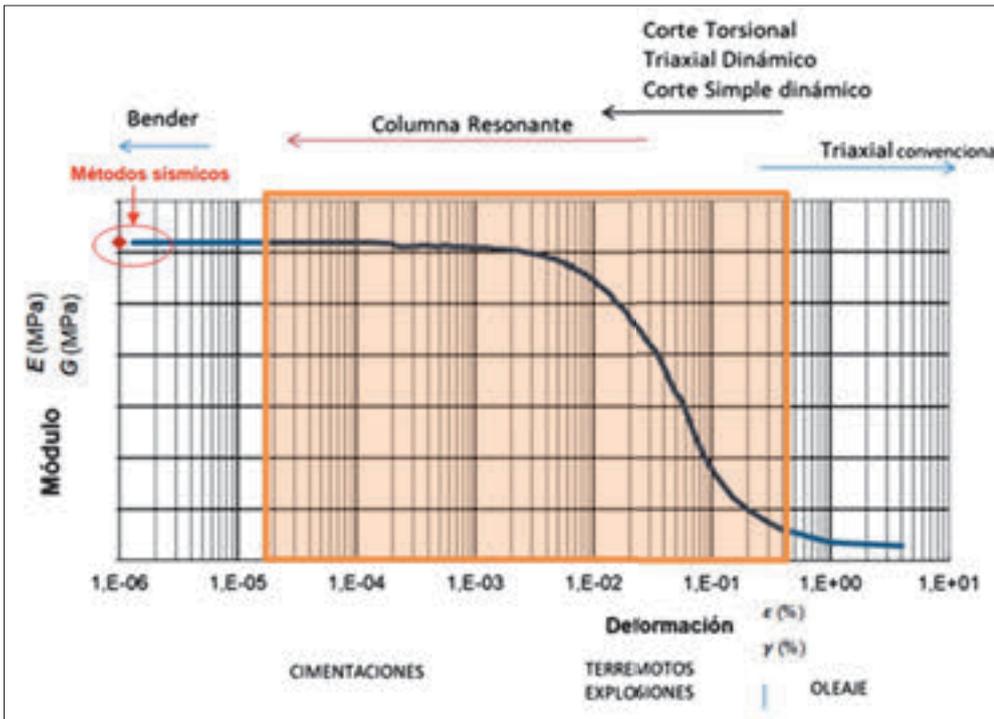
General view of the resonant column and cyclic torsional shear equipment at CEDEX Geotechnical Laboratory.

Among the equipment for dynamic soil tests, the Geotechnical Laboratory of CEDEX has a device that's capable of executing resonant column and cyclic torsional shear tests on the same soil specimen. The union of both tests allows to obtain, in a wide range of shear strain, the dynamic shear modulus, G, and the damping ratio, D, fundamental parameters to study the performance of soils under dynamic stresses.

Among the equipment for dynamic soil tests, the Geotechnical Laboratory of CEDEX has a device that's capable of executing resonant column and cyclic torsional shear tests on the same soil specimen. The union of both tests allows to obtain, in a wide range of shear strain, the dynamic shear modulus, G, and the damping ratio, D, fundamental parameters to study the performance of soils under dynamic stresses. The two techniques are based on the application of a time variable torsion on the upper part of a soil specimen that's fixed at its base to the pedestal of a triaxial cell. However, to obtain the dynamic parameters, different physical principles are applied, in such a way that this equipment makes it possible to link, with a continuous curve, the different G and D values obtained with different methods and calculations. The deformations obtained in these two tests are different, so the great advantage of combining both techniques in a single device is that it's possible to study the variation curves of the shear modulus and damping in a very wide range of shear strain.

The system is mounted on a triaxial cell, so it's possible to saturate the sample, measure the pore pressure, control the volume change, and apply different confining pressures. Specimens from undisturbed samples and remoulded specimens from both sandy and clay materials can be tested.

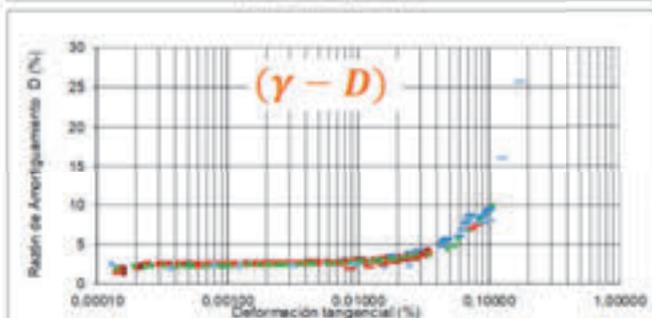
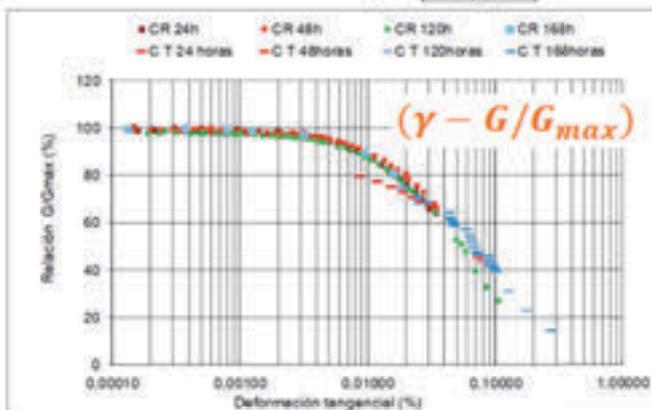
| Shear strain range, γ (%) | Resonant column | Torsional shear |
|----------------------------------|-----------------|---------------------|
| | | $10^{-5} - 10^{-1}$ |



Shear strain obtained by the different methods used to study the dynamic properties of soils. The wide range swept by the resonant column and cyclic torsional shear tests is indicated.

TRABAJO MUESTRA PROBETA COLUMNA RESONANTE -CORTE TORSIONAL

| | G_{max} (MPa) |
|----------|-----------------|
| 24horas | 106.5 |
| 48horas | 112.5 |
| 120horas | 125.1 |
| 168horas | 126.9 |



Example of the results obtained after performing the resonant column (CR) and torsional shear tests (CT) on a specimen cut from an undisturbed sample.

The great versatility of the device allows to study with precision the following factors that significantly influence the dynamic performance of the soil:

- Shear modulus G for very small shear strain, G_{max}

- Variations of shear modulus G and damping ratio D as a function of:

- Shear strain, γ ,
- consolidation time
- confinement pressure

- The possibility of liquefaction or cyclic mobility taking place

APPLICATIONS

- **Maritime and port engineering**

Analysis of the effect of wave load on the ground

- **Seismic engineering**

Analysis on the effect of the seismic load on the ground. Liquefaction

- **Railway engineering**

Analysis of the effect of the dynamic load of trains on the track layers and embankments

- **Transportation engineering**

Analysis of the effect of the dynamic traffic load on the subgrade layers and on the embankments

SUSPENSION PS-LOGGING (PS-LOGGING)

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Measurement system with the probe inserted in a borehole.

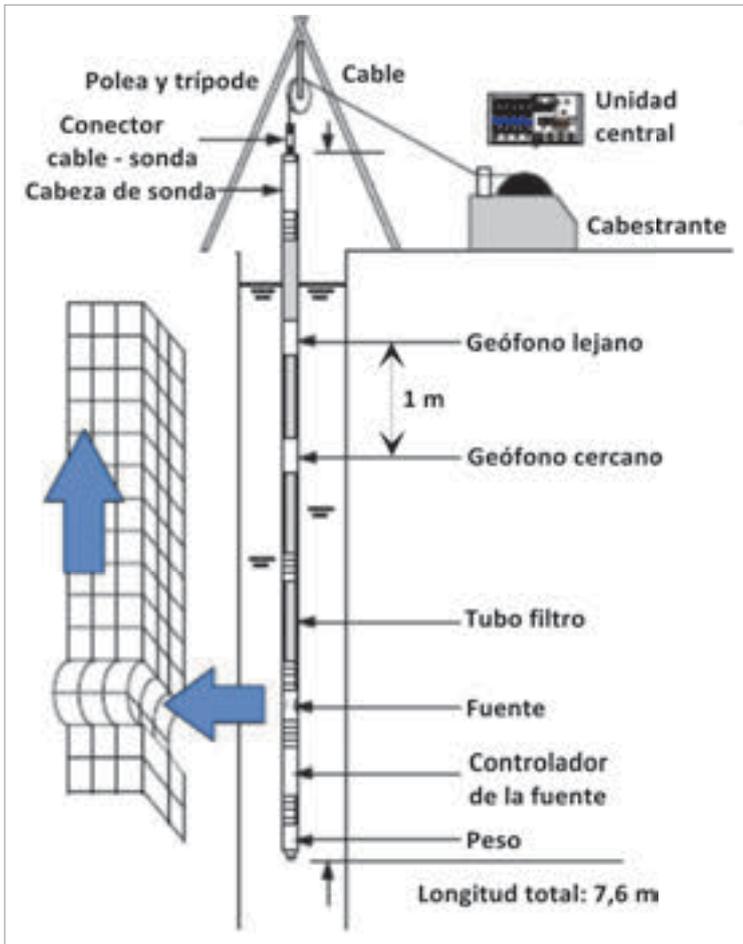
Suspension PS-Logging probe allows to carry out seismic tests inside boreholes. It's developed to determine the propagation velocities of both longitudinal (P) and transverse (S) seismic waves, V_P and V_S respectively, in the ground surrounding the walls of a borehole at any depth. The propagation velocities of these waves only depend on the physical properties of the medium through which they travel and not on the source that generates them. Therefore, these propagation velocities are a useful indicator of the compactness of the particles in the ground.

The great potential of seismic methods lies in the fact that once V_P and V_S are known, it's possible to calculate the dynamic moduli of stiffness of the studied materials. These parameters allow to determine the strain response of soils under the application of stresses or loads. Specifically, to calculate the dynamic shear modulus (G), a fundamental quantity for the mechanical characterization of the soil, it'll be only necessary to obtain V_S and to know the density (ρ).

The probe is specially designed for the study of soils and soft rocks and its main advantage, compared to other seismic techniques that can be developed inside boreholes, is that it only needs one borehole to carry out the test.

Two geophones are installed in the probe, 1 m apart, and an impulsive electromagnetic source to generate a vibration in the ground that will be logged by both sensors. The difference in arrival times of the waves to each geophone will be used to calculate the average propagation velocity of the waves in the section of ground between them. The system basically consists of a pulley mounted on a tripod; a winch with a cable winding that allows the movement of

| Poisson's ratio (ν) | Shear Modulus (G) | Young's Modulus (E) |
|---|-----------------------|-------------------------|
| $\nu = \frac{\frac{1}{2} \left(\frac{V_p}{V_s} \right)^2 - 1}{\left(\frac{V_p}{V_s} \right)^2 - 1}$ | $G = \rho V_s^2$ | $E = 2(1 + \nu)G$ |



the probe along the borehole and also a central unit arranged at the surface that controls the test and records the signals measured by the geophones.

In order to carry out the test, it's necessary that the borehole be flooded, since the specific disturbance generated by the source has to reach the ground through the borehole walls. This propagation occurs through the wave that is generated in the fluid due to the pressure gradient produced by the action of the source. This pressure wave generates seismic waves (P and S) in the borehole walls due to the contact between fluid and ground. If a casing pipe is needed to ensure the stability of the borehole walls, a PVC pipe, not metallic, will be used for a good transmission of the waves.

Components of the suspension PS-Logging probe, and a sketch of propagation of the waves on the ground.

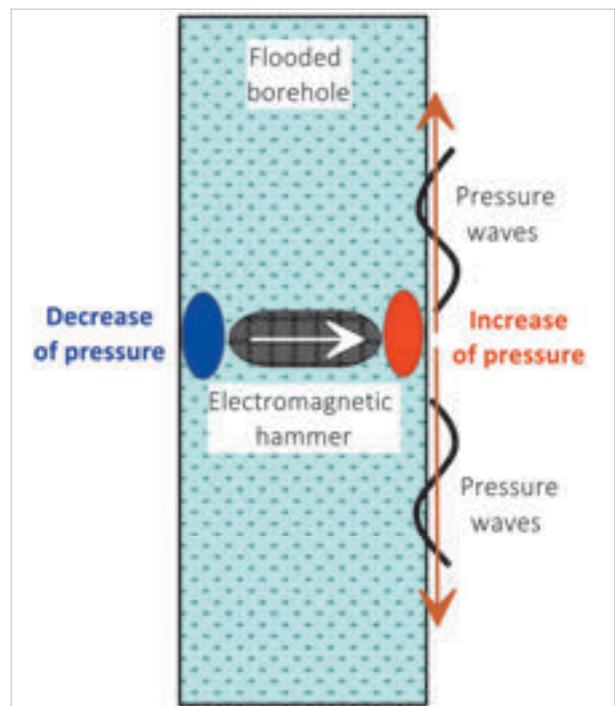


Data acquisition with the PS-logging probe in the expansion works of the south dock of Huelva port (2020).



Data acquisition with the PS-Logging probe in the Aguas Teñidas tailing dam (2019).

Propagation of the impulse generated by the source.



Some works carried out by the Geotechnical Laboratory (CEDEX):

- Study of the consolidation of hydraulic landfills (port of Cádiz)
- Determination of the V_{s30} value for the calculation of foundations (ARUP)
- Determination of the variation of V_s with depth (port of Ibiza)
- Study of the evolution of the setting of jet grouting columns (port of Valencia)
- Study of the variation of shear resistance with depth in tailing dams (Minas de Aguas Teñidas, S.A.)
- Study of the efficacy of soil improvement using injections (El Búrdalo dam)

APPLICATIONS

- Determination of the layer structure of the ground from the study of the propagation velocity of seismic waves
- Obtaining the maximum value of the dynamic moduli (shear modulus and Young's modulus)
- Evaluate the efficacy and temporal evolution of soil improvement techniques
- Studies of consolidation processes in soils
- Obtaining V_{s30}

