OPPBTP
La prévention BTP

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First studies of exoskeleton use in construction industry

SEC / APST / OPPBTP

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Plan

I. Presentation of the study, the partners and the methodology

II. Key lessons of the three observed practices

- Facilitate loads handlings
- Alleviate operators of their work equipment weights
- Alleviate operators during ceilings work with a sander

III. Summary and futures expectations

Study starting points

- The **OPPBTP** is keeping a permanent watch on innovations and new practices
  - Observations of the development of exoskeleton offers
    - ✓ Commercial arguments : reduction of musculoskeletal problems
  - Lack of scientific knowledge about this thematic

- Project about exoskeleton initiated by the ***Syndicat des entrepreneurs de la construction (SEC)***
  - Companies and exoskeleton models already identified
    - ✓ **Type of exoskeleton : harness without motorization** with 1 or 2 arms
  - Partnership with the OPPBTP requested

- Common study project with gathered SEC / APST / OPPBTP
  - APST Health and safety department for construction industry

Study main principles

- **Objectives**
  - Generate useful knowledge about exoskeletons use
  - Identify food for thought to initiate extensive studies

- Retained principle : **comparative analysis** of the changes done
  - Activity observations **without** and **with** exoskeleton
  - Work sequences video recording
  - Operators interview
  - Analysis with the “CAPTIV” app

  - Interviews with companies to determine technical and organizational evolutions which could avoid using exoskeletons

Work hypothesis and metrology associated

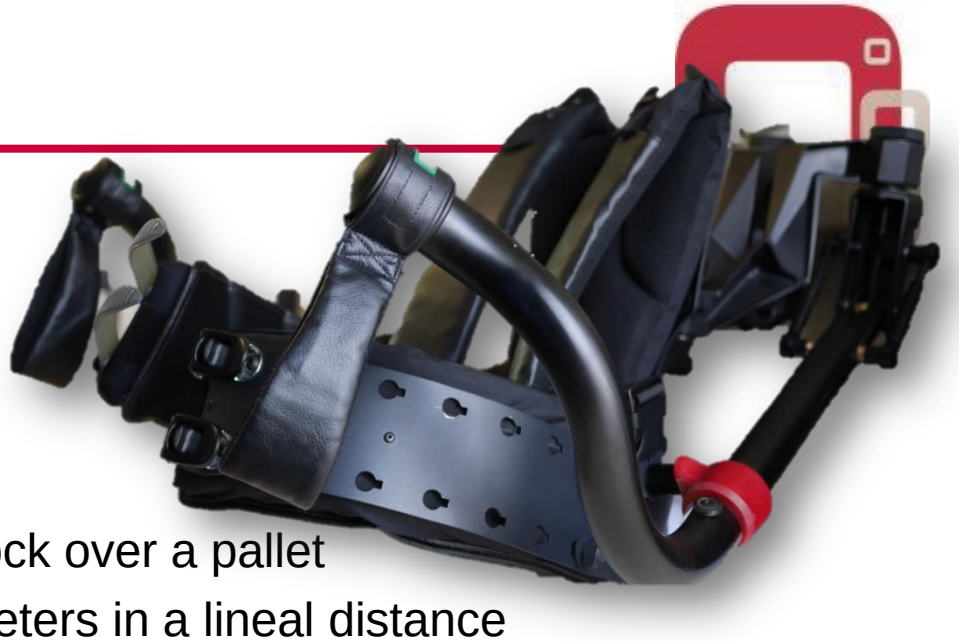
- **Is it neutral to carry an exoskeleton?**
  - Postural compensation phenomenon?
    - ✓ Exoskeleton weight and bulk
    - ✓ Large distance of the load
    - ✓ Professional gesture : preservation or modification?
  - Angle measurements of the trunk and upper limbs
    - ✓ Test of electromagnetic sensors specific to the construction industry
    - ✓ Restrictions: electromagnetic sensors sensitivity
- **What about efforts reduction?**
  - Cardiofrequencemeter
    - ✓ Restrictions: vibrations and electromagnetic radiations sensitivity
    - ✓ Touchy illustration depending on observations

Exoskeleton uses

- Uses being determined by SEC companies
  - **Use 1 : handling**
    - ✓ Movement with a load : Impossible to implant a breeze block storage pallet very close to the workspace
    - ✓ Does the use of an exoskeleton contribute to decrease the level of demands ?
  - **Use 2 : Lighten the operator from its work equipment weight**
    - ✓ Use possible with chainsaw, chisel, grinder
- Used in a company which have co-developed its own exoskeleton
  - **Use 3 : Celling work** with a sander
  - Arms above head
  - To reduce efforts and maintain work quality

Use 1
Breeze blocks handling

Handling use



- Type of exoskeleton
- Breeze block handling
  - Assembly
    - ✓ Possibility to take a breeze block over a pallet
    - ✓ Possibility to move up to 15 meters in a lineal distance
    - ✓ Possibility to install the breeze block during a wall construction
  - Disassembly
    - ✓ Possibility to take a breeze block over a wall
    - ✓ Possibility to move
    - ✓ Possibility to drop off the breeze block on the pallet
- Two types of breeze block
  - « light » breeze block = 12 kg Assembly/Disassembly of 8 of them
  - « heavy » breeze block = 28 kg Assembly/Disassembly of 13 of them

Posture due to exoskeleon use

- Operators arms held up by the “exoskeletons arms”
- But:
  - Load kept away from the body
  - Forward attracting force
  - Offset by back movements

Usual charging port posture

- Load pressed against the body as close as possible from his center of gravity
- Required a sustained effort over the exoskeleton arms to maintain the load at the operator’s natural position

Professional gestures modifications

- Research of the most adapted way to hold a breeze block

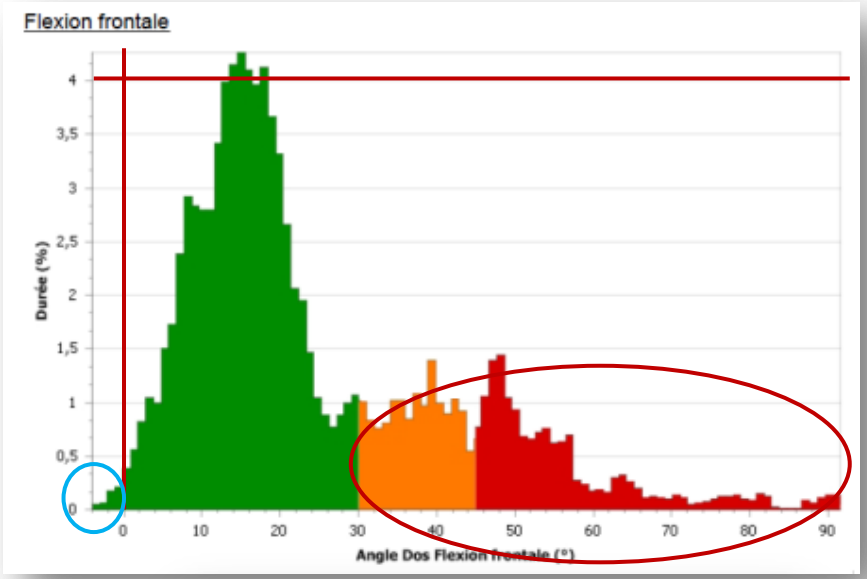
Professional gesture modifications

- Operator arms immobilized during movements without load
  - Decrease recovery strategy
- “Exoskeleton arms” blockade during movement
  - Restrictive and additional gestures

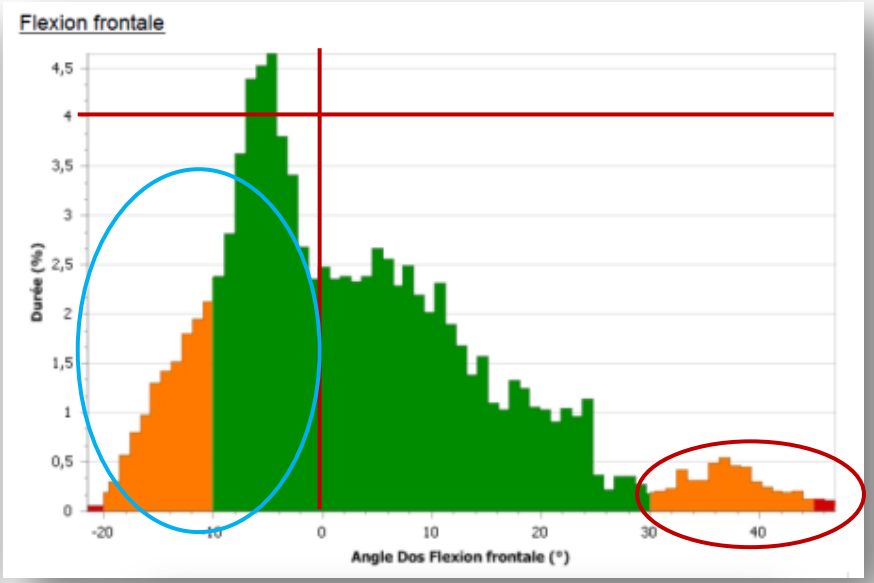
    to engaged/triggled the “exoskeleton arms”

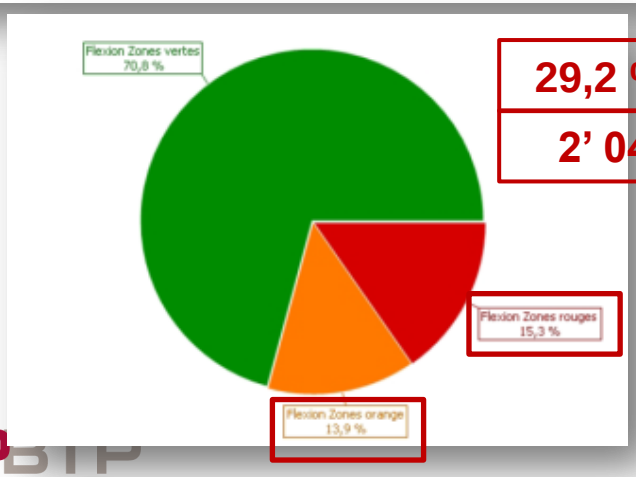
« light » breeze blocks : assembly/disassembly task

Without exoskeleton (7’ 06”)



With exoskeleton (14’ 40”)



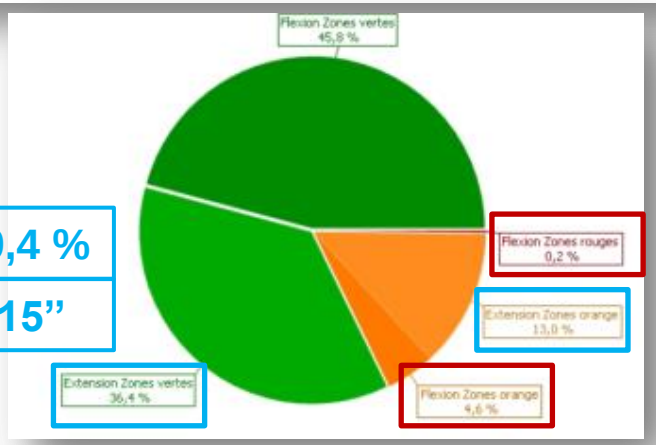


29,2 % à 4,8%

2’ 04” à 42”

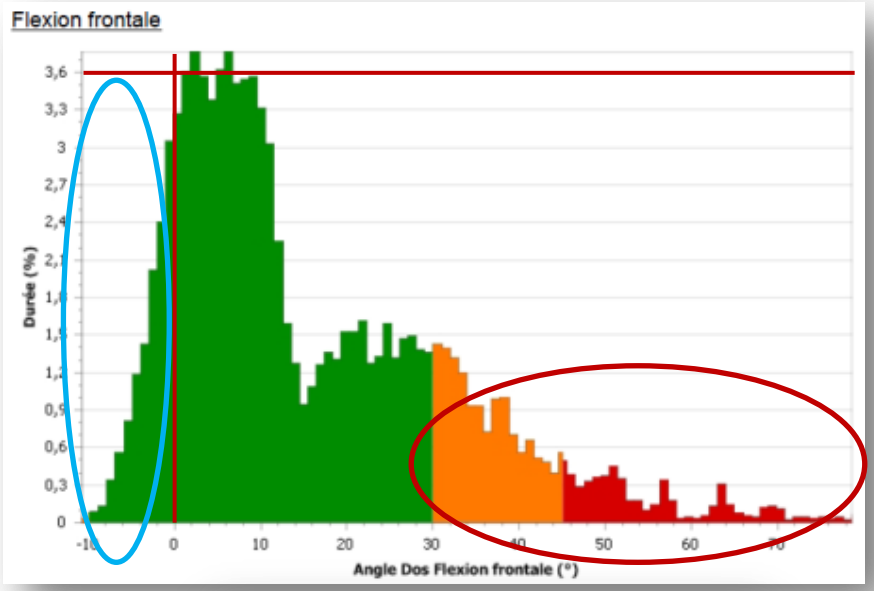
1 % à 49,4 %

8” à 7’ 15”

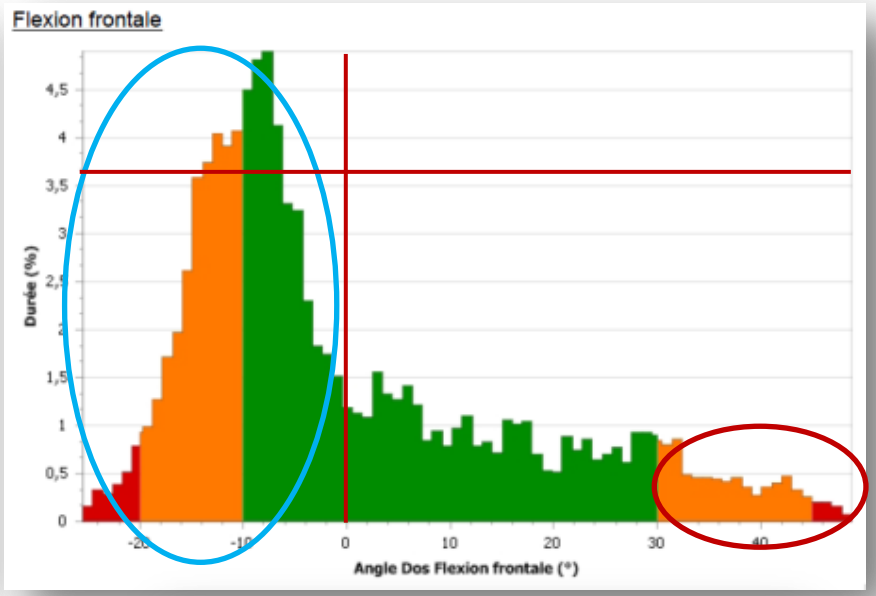


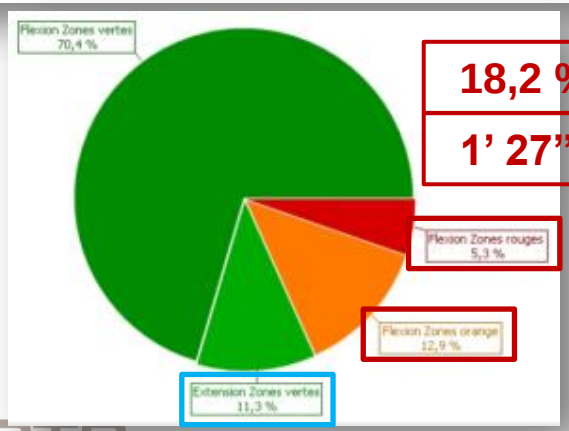
« heavy » breeze blocks : assembly task

Without exoskeleton (7’ 56”)



With exoskeleton (19’)



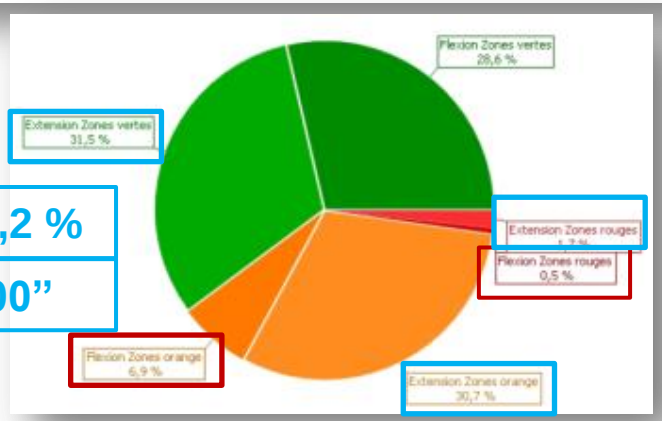


18,2 % à 7,4%

1’ 27” à 1’ 24”

11,3 % à 63,2 %

54” à 12’ 00”



Summary

- **This non-motorized exoskeleton with a load manual prehension isn’t adapt to handling tasks requiring any movement**
  - ✓ Spending more time
  - ✓ Offsets movements
  - ✓ Increased heart rate

- Looking for other solutions to help handling and which include gripping, movements and position of breeze blocks on the wall

Use 2
Lighten the operator from its work equipment weight

Without exoskeleton = 4’ 06”

With exoskeleton = 5’ 41”

Main analysis

- Need of specific system for each equipment
- The arm design influenced postures as well as the gripping of equipment
- Safety
  - Feeling of « being attached », to not have anymore the control of the work gesture
  - News safety rules (individual and collective)
  - Maybe considered a specific training? A preliminary time of taking in hand?
- Benefit when work is at shoulder-high
  - Adaptability limited work construction industry

Use 3
Ceilings work with a sander

Main analysis

- Real decrease of the effort asked
  - Operators feel a decrease of about 60%
  - 800 m² ceiling: from 5 to 1,5 days
  - Quality like the original
  - Delicate control of the gesture amplitude

- Design step by step depending on the task analysis requirement
  - Recognition of a “hard” position
    - ✓ Share between operators and management
  - Decreasing efforts while keeping work quality and work gesture
  - Approach step by step
    - ✓ Research, test and assessment of adapted equipment
    - ✓ Improvement of the solution with the maker

Summary and discussions

Summary and discussions -1

- Teachings about this kind of exoskeletons
  - Restricted contributions for construction industry
    - ✓ Except if the work is done at shoulder-high
  - Heading for helping equipment to Carry work equipment
    - ✓ Preservation of the professional gesture
    - ✓ Adapted to construction industry

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- Methodology
  - **Starting from knowledge of the task and of a production process global analysis to determine appropriate means**
    - ✓ Actual exoskeletons do not necessarily correspond to the most adapted solution nor to the priority

Summary and discussions - 2

- First-generation of professional exoskeletons
  - Time of « trial and error »
  - Important evolutions required before any real use to help human to work
- To better future actions
  - Structure knowledge and experience feedback
  - Establishment of an cross-sectorial observatory about exoskeletons
    - ✓ National level ? European level ?
  - Construction industry observatory in progress of structuration by the OPPBTP

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Thank you for your attention