METAL REPLACEMENT

STRUCTURAL COMPOUNDS
The use of metal in the field of structural elements has accompanied man’s technological development since ever.

Resistance, stiffness and hardness of these materials and their alloys allow the manufacture of items that can bear heavy loads and stresses, such as those required inside buildings, vehicles, and machinery.

Due to the ever stricter requirements of modern design, engineers pay special attention to synthetic materials manufactured from thermoplastic or thermosetting polymers.

Compounds and composites are currently successfully used in metal replacement applications, where the required mechanical performances are as important as those of metals.

However, polymers provide further advantages: reduced weight thanks to the lower densities, chemical resistance, easy production process waste conversion and management, possibility to form complex shapes without expensive processing and assembly.

As far as cost containment is concerned, these advantages lead to immediate cost reduction, increasingly rapid development and introduction of new ideas to the market, and greater resources and environmental respect.

LATI, a leading company in the field of technical compounds, offers today a wide and complete range of compounds designed for metal replacement based on different thermoplastic matrices, from polypropylene to polyetheretherketone, from conventional polyamides to high performance matrices such as polyphenylene sulphide and aromatic polyamides.

Along with its compounds, LATI also offers to its customers advanced support services: technical assistance in conversion and design, research and development, custom-tailored formulations.

A global offer consolidated by many decades of experience that only a protagonist in the history of compounds can provide.
The introduction of structural technopolymers in metal replacement projects requires caution and experience.

Careless or hasty solutions may lead to underdimensioned or overdimensioned products with consequent damage and waste of time in both cases.

Hesitation – for fear or lack of knowledge – in introducing compounds in a project may cause substantial losses and is an anachronistic choice.

LATI is aware of these difficulties, and therefore offers its customers a range of resources which help entering the world of technical compounds.

**Co-design Service:** offers design support by means of finite element structural and fluid dynamic calculation. Simulation results provide a first indication of feasibility or an answer to concrete problems concerning resistance, life expectancy, deformation, and filling.

It is worth mentioning that LATI co-design service also considers specific aspects of polymers which are often neglected during the design phase when there is no thorough knowledge of the subject:

- nonlinearity of stress-strain ratio;
- temperature effect;
- effects of environmental conditions;
- creep and fatigue;
- presence of inserts and post-processing.

Neglecting even a single one of these factors may lead to wrong conclusions and consequent practical problems.

Simulations are carried out by technicians with almost 20 years experience in this field, on the basis of customer-supplied geometries and using mechanical and rheological characterization obtained in compliance with the conditions of use.

**Molding assistance service:** Manufacturing with high reinforced and sophisticated compounds may not be an easy task. Obtaining maximum results from the material chosen is certainly also difficult.

In order to help solving these problems, LATI technicians with thirty years experience in injection molding, injection molding machines, are at customers’ disposal.

**Research & Development service:** Giving tailored answers to meet customers’ requirements is part of LATI’s mission.

Each special compound can be reformulated and optimized in order to meet project requirements with maximum accuracy, even with remarkable deviation from catalog materials.

For this purpose, LATI’s advanced R&D center always pays special attention to the market demand and supply, and has often proposed and developed solutions that later proved pioneering even worldwide.

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Values shown are based on testing of injection moulded laboratory test specimens, conditioned according to the practice and represent data that fall within the standard range of properties for non-coloured material, if not otherwise specified. As they may be subject to variations, these values do not represent a sufficient basis for any part design and are not intended for use in establishing values for specification purposes. Properties of moulded parts can be influenced by a wide range of factors including, but not limited to, colorants, part design, processing conditions, post-treatment conditions, environmental conditions and usage of regrind during the moulding process. If data are explicitly explicitly indicated as provisional, range of properties has to be considered wider. This information and technical assistance are provided as a convenience for informational purposes only and are subject to change without notice. The customer shall always ensure that the latest release of technical information is at his own disposal. Lati S.p.A. extends no warranties, issue any immunities or assume any liabilities on behalf of Lati S.p.A. except in a writing signed by a specifically authorised Lati S.p.A. executive. Unless otherwise agreed in writing, the exclusive remedy for all claims is replacement of the product or refund of the purchase price at Lati's option, and in no event shall Lati S.p.A. be liable for special, consequential, incidental, punitive or exemplary damages. No information herein can be considered as a suggestion to use any product in conflict with intellectual property rights. Lati S.p.A. disclaims any liability that may be claimed for infringement or alleged infringement of patents. Unless specifically stated in writing, the products mentioned herein are not suitable for applications in the pharmaceutical, medical or dental sector, in contact with foodstuff or for potable water transportation. For any other issues Lati S.p.A. Conditions of Sales apply. Copyright © LATI S.p.A. 2013 LATI does not guarantee that the data contained in this list are current, complete and error-free. To double check the values, users are kindly requested to contact LATI Technical Assistance or commercial network. LATI Industria Termoplastici S.p.A. declines all responsibility arising from any use of the information described in this document.
HOW TO CHOOSE?

The choice of compound that best meets the project requirements is the first brick of the winning approach to an idea.

Accurate design and cost analysis are an integral part of a development strictly based on the right choice of material.

In order to determine which of the numerous solutions offered by the market is the most suitable for a successful project, the following questions should be answered:

1. What **mechanical performances** are necessary? The presence of only static loads requires different solutions compared to conditions also involving impulsive stresses, such as impacts and vibrations.

2. In what **environment** will my manufactured item be operating? Factors such as chemical attack, exposure to sunlight and bad weather or atmospheric humidity play an important role in polymer resistance.

3. What **temperatures** are involved? Heat causes remarkable changes in mechanical performance of polymers; therefore, an evaluation of maximum and minimum project temperatures is essential.

4. What **life expectancy** is required? Compounds are subject to physical ageing phenomena, creep and relaxation; these factors may even cause a substantial change in the mechanical behavior of material over time. If these factors are not adequately taken into account, a dramatic error may arise.

5. What **safety factor** should I adopt? The different properties of metals and polymers require attention and prudence during design.

6. What other properties are required by my product?

7. Many other issues are often connected to a structural compound: it must be selfextinguishing, food contact compatible, selflubricating, semiconductive...
   All these requirements may involve a complex solution.

The last question - even though it is seldom the last one - that needs to be answered is the following:

8. How much can I spend?

A winning idea is conveyed to the market by also a fair and competitive price.

This factor often causes some aspects related to the real performance of the product to be neglected and underestimated.

However, the successful use of polymers requires the awareness that the costs arising from a wrong choice may be very high, especially if mould changes, or production chain or, worse, the withdrawal of finished products from the market are involved.

This guide aims to be a tool for finding an answer to these questions.

LATI structural compounds are presented herein along with a partial overview of the products available today.

However, the determination of advantages and disadvantages of the main products is a major tool for the orientation in a (often too) rich market supply.
LATAMID: PA6 & 66

Among the most popular thermoplastic resins, polyamides 6 and 66 are best suited to the production of structural compounds with excellent price/performance ratio. The many advantages of conventional polyamides include a very easy moulding, a process that requires neither special equipment nor measures nor specific experience.

Furthermore, more complex formulations may be realized in order to meet all kinds of project requirements: from self-lubrication to self-extinguishing, from antistaticity to high aesthetics.

Characterized by a very good chemical resistance, especially to aggressive organic agents, these materials are suitable for use in applications in direct contact with hydrocarbons, solvents, and oils.

With the necessary precautions, these materials may be used even in the presence of water or high temperature aqueous solutions, as, for instance, in heating/cooling circuits.

However, the best results are obtained in the structural field where up to 60% glass-reinforced or up to 50% carbon-reinforced grades may be used.

Mechanical data confirm that PA-based compounds may exceed 2000 kg/cm² ultimate tensile strength with elastic moduli between 15000 and 28000 MPa.

Heat resistance is also excellent, allowing continuous operation even above 120°C.

The extremely interesting properties for the designer engineer include excellent creep and fatigue performance.

First step in metal replacement, PA66-based compounds represent an alternative to low-profile conventional metallic materials, such as zamak or die casting aluminium alloys, thanks to similar mechanical performances, obtained with much lower specific weights.
Moreover, unlike the previously mentioned metals, PA conversion requires far less energy and allows obtaining finished products without further cleaning, removal of flashes and scraps, etc., thus ensuring remarkable savings in terms of time, money, and resources.

The limits of these compounds are almost exclusively, their performances at high temperatures: above 130°C, more performing and expensive polymers have to be chosen.

Moreover, base resins tend to absorb moisture and this characteristic often also represents a limit.

On one hand, compounds are tougher thanks to this characteristic, but on the other hand, it causes losses in the elastic modulus and dimensional changes.

Application fields cannot be determined with accuracy: the use of PA6 and PA66-based structural compounds concerns practically all industrial segments, with the only exclusion of those involving very high temperature and prolonged exposure to hot water or strong acids/alkalis.

30%, 50%, and 60% glass fibre reinforced PA are among the most successful structural compounds not only thanks to their properties, but also to a high use flexibility and a very interesting price.

Fig. 5 In polyamides, the lower the moisture absorption, the lower the dimensional changes due to environmental humidity absorption.

Fig. 6 LATAMID 66 H2 G/30: as the reinforcing fibre content increases, the dimensional change of manufactured item due to environmental humidity, decreases.

Fig. 7 Applications built as an alternative to traditional metallic materials for low-profile
METAL REPLACEMENT

STRUCTURE AND AESTHETICS: LATIGLOSS

Complete metal replacement also involves the imitation of exterior appearance: **glossy, smooth, without defects.**

This result may be difficult to obtain with traditional structural compounds, typically featuring a very bad surface appearance – especially on high thicknesses – due to the natural migration of reinforcing fibres.

In order to solve this problem, LATI has developed the LATIGLOSS compounds, i.e. structural compounds with excellent aesthetics.

LATIGLOSS products are based on PA6, 66 or PPA, in which a high fibre or carbon content is dispersed in a special matrix.

The result is a typically structural compound allowing obtaining defect-free, smooth and even surfaces.

Thanks to its excellent appearance, the produced item does not require any further painting nor special mould finishing (embossing, electrical discharge machining, etc.).

LATIGLOSS products can also be subjected to **metallization** without the risk of obtaining bad surface appearance, such as poor gloss due to substrate defects.

Besides reinforcement, LATIGLOSS polyamides provide further advantages based on formulation and surface quality:

- selflubrication;
- improved fatigue strength;
- higher dimensional stability compared to the analogous grade with standard formulation.

Fig. 8 LATIGLOSS 57 G/50: stress-strain curves in temperature.

Fig. 9 LATIGLOSS 57: stress-strain curves of saturated and conditioned material (ISO 527).

Fig. 10 LATIGLOSS 66 H2 G/50: stress-strain curves in temperature (ISO R 527).

<table>
<thead>
<tr>
<th>MATERIAL</th>
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<td>STEEL C40</td>
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</table>

Fig. 11 Metal replacement: comparison of density and mechanical performances of metals and structural compounds.
LATIGLOSS grades have been developed and marketed to offer a concrete opportunity to not only replace metal, but also more expensive and performing structural compounds (such as PAA, PA6T, etc.) which are often chosen for their aesthetic characteristics rather than for their high thermal performances.

LATIGLOSS compound is therefore recommended when a PA66 with improved aesthetic is required or a semi-aromatic polyamide is used without exploiting its excellent thermal and chemical properties.

LATIGLOSS family includes grades suitable for contact with drinking water, especially designed for medical and food applications.

* International standards for testing and quantification of bacterial activity and the action of microorganisms on surfaces.
PPS: LARTON

Polyphenylene sulphide is a resin suitable for manufacturing structural compounds featuring not only excellent mechanical performances, but also allowing the use of manufactured items at high temperature ranges of about 200°C.

Thanks to its chemical nature and molecular structure, PPS is particularly resistant to temperature action and typically related effects, especially creep.

PPS offers a superior chemical resistance allowing its use in aggressive environments involving – even continuous – exposure to oils, even chlorinated solvents, hydrocarbons, and also a large number of acids and inorganic alkalis.

PPS is totally non-hygroscopic and does therefore not absorb environmental humidity.

Unlike, for example, polyamides, it is not subject to dimensional or performance changes depending on weather conditions.

PPS items typically feature an excellent dimensional stability and can be injection-molded without particular problems.

As far as mechanical aspects are concerned, PPS is provided with high glass and carbon fibre content.

Such compounds feature high stiffness, good ultimate tensile and bending strength, and especially high reliability over time in terms of relaxation and creep resistance as well as fatigue strength.

It should be underlined that creep performance in PPS indicates that this material is best suited to the manufacture of items requiring stability in terms of shape, load support, and life over time, even for several years, without the risk of sudden breakdown or gradual loss of functionality.

Even though reinforced grades already feature an excellent dimensional stability, compounds containing a mixture of mineral charges capable of minimizing deformation caused by the molding process are also available.

Finally, it is worth mentioning that thanks to the intrinsic self-extinguishing property of PPS-based compounds, many formulations, e.g. 40% glass fibre reinforced compound, show UL94-V0 self-extinguishing properties at different thicknesses.

However, limits of PPS require caution, especially during the design phase.

In fact, this material is relatively fragile: due to its low ultimate elongation, it cannot support apparently low deformations, as in the case of clips, forced inserts, slight interference fit coupling, etc.

Besides, PPS is hardly machinable and therefore not suited to postprocessing of any kind, second operation, fastening by means of self-tapping and self-shaping screws.

Electrical performances are also low, with tracking resistance of only 125V.

In metal replacement, PPS is therefore recommended – e.g. in 40% glass fibre or 30% carbon fibre versions – for the production of pieces:

- featuring high stiffness, dimensional stability and compliance with project tolerances;
- to be used in hostile chemical environment;
- subjected to high temperatures up to 200°C;
- requiring high reliability over time and therefore creep, relaxation and fatigue resistance;

Typical application fields: automotive, chemical industry, precision mechanics, hydraulics, alternative energies.

In Fig. 15 LARTON G/40: stress-strain curves at different temperatures show high stiffness of PPS.
METAL REPLACEMENT

LATI’s experience in PPS conversion has led to the development of a wide range of compounds for structural applications.

In particular, LATI has been able to reduce the effects of intrinsic polymer fragility thanks to the development of special PPS versions allowing up to 50-60% ultimate elongation values increase compared to conventional products.

Such formulations, called I6 and I9, allow manufacturing parts subject to deformation without affecting mechanical properties.

Another very interesting PPS compound is the special glass fibre reinforced version indicated as D6, which is a structural grade offering outstanding mechanical properties of traditional PPS grades but features very low differential shrinkages leading to highest dimensional stability on moulded parts.

Fig. 16 LARTON G/40: creep data show a high capability of retaining their functionality over time.

Fig. 18 LARTON G/40: fatigue resistance.

Fig. 19 LARTON G/40 warpage of traditional glass fibre reinforced compound vs D6 formula.

Fig. 20 Special knife textile (weaver machine) LARTON G/40 NERO:3355.
PPA: LARAMID

The excellent properties of this resin group can be further improved by the addition of aromatic groups into the molecular structure of polyamide.

**Thermal and chemical properties**, in particular, are remarkably improved in PPA.

**Temperature resistance** generally increases by over 40-50°C compared to PA6, allowing this material to be used, for example, even in very hot environments, such as vehicle engine compartments or inside of boilers, compressors, and electrical equipment.

Characterized by **high chemical resistance** to all aggressive organic acid PPA also features a quite good resistance to inorganic acids and bases, and is less hygroscopic than PA66.

The possibility of introducing high quantities of reinforcing fibres into PPA allows manufacturing compounds with extraordinary mechanical properties, especially in terms of ultimate tensile strength, impact resistance, and elastic modulus.

As regards metal replacement, PPA-based compounds meet the highest requirements thanks to their ultimate tensile strengths of about 3000 kg/cm² (300 MPa), and elastic moduli over 25000 MPa in 60% glass fibre reinforced versions.

Compared to PPS, PPA is often in competition with PPS, PPA features more flexibility when small local deformations, post-processing, forced assembly, as well as overmolded metal inserts, high thickness (poorly tolerated by PPS), impacts and stresses assimilable to impulses are involved.

PPA limits are mainly connected with processing some experience is required in order to obtain dimensionally stable and good appearance products fully exploiting the superior mechanical properties of compounds.

PPA based materials are suited to structures required to have the following features:

- ultimate tensile strength and modulus directly comparable to some aluminium or zamak metal alloys;
- best heat resistance;
- resilience and ability to sustain impacts and vibrations;
- easily machinable.

**PPA is widely used as a high performance version of PA and direct alternative to PPS**, and is therefore commonly used in the fields of automotive, furniture, construction of elements for pressure vessels, actuators, pump parts, engines, etc.

Among the most interesting proposals of LATI range are of course structural compounds with high glass fibre content from 30 to 60%.

For high demanding metal replacement requirements, products with maximum glass content can offer extraordinary results.
PEEK: LARPEEK

PEEK polymer is a top technical thermoplastic material with superior properties, designed for continuous using temperatures up to 260°C.

This polymer may be simply defined as one of the best performing thermoplastics from all viewpoints (chemical, tribological, thermal, toxicological, etc.).

However, it has to be stressed that the quite high price of this material suggests adopting it when no alternative is available or in order to avoid any risk.

Like PPS-based structural compounds, for example, PEEK-based compounds are proposed in up to 50% glass fibre reinforced and up to 45% carbon fibre reinforced versions.

Reinforcement being equal, PEEK grades, however, are not better than other much less expensive ones, notwithstanding their superior matrix properties.

So LARPEEK compounds are only recommended when very high temperatures or conditions of severe chemical attack are involved.
High Elastic Modulus: HM Materials

In some applications, metal is used for its minimum deformation under working load.

In such cases, the best performing structural compound might ensure stress resistance, but not the required stiffness, thus showing deformation above a certain acceptable limit.

To this purpose, LATI has developed a family of compounds provided with a particularly high elastic modulus which is over twice that of conventional structural materials.

**HM (High Modulus)** materials are obtained from high modulus 40-45% long carbon fibre reinforced high performance matrix (PPA, PPS, PEEK).

Such reinforcing fibres are longer than conventional chopped strands.

Materials thus obtained substantially feature the same performance as the corresponding conventional grades, but with much higher elastic modulus and, therefore, a reduced deformation under the same load.

Tests carried out have also shown a general improvement in fatigue behaviour compared, for example, to a conventional 30% carbon fibre.

Improved compound formulation requires no specific handling or processing equipment, as dedicated moulding techniques, tools and machinery.

All HM compounds can be injected as any other carbon fibre reinforced thermoplastic compound. Tools have to be built using the same steel types and surface hardening treatments that are normally selected for glass or carbon fibre highly reinforced grades.

With HM compounds the challenge for metal replacement meets its highest levels, offering new exciting opportunities to step into application fields never explored by synthetic materials, with interesting options for the bottom line cost of finished parts as well.

Designed to meet typically mechanical requirements, HM compounds are suited to metal replacement in applications where absolute operating precision is a prerequisite:

- robotics and automation,
- textile industry,
- precision mechanics,
- military and aerospace industry.
### Metal Replacement

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<th>Testing conditions</th>
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<th>PES</th>
<th>PPH</th>
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### Physical Properties

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<td>×10E-6 / °C</td>
<td>10</td>
<td>4</td>
<td>20</td>
<td>8</td>
<td>8</td>
<td>15</td>
<td>10</td>
<td>3</td>
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<tr>
<td><strong>Self-extinguishing</strong></td>
<td></td>
<td></td>
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### Features

- UL approved grade
- Intrinsically self-extinguishing base resin
- Flame retardant material-LATI tested
<table>
<thead>
<tr>
<th>LATOMID 12</th>
<th>G/50</th>
<th>LATOMID 6</th>
<th>S/30</th>
<th>LATOMID 6 H2</th>
<th>LATOMID 6 H2</th>
<th>LATIGLOSS 62</th>
<th>G/65</th>
<th>LATOMID 6 H2</th>
<th>G/50</th>
<th>LATAMID 66</th>
<th>H2</th>
<th>G/50</th>
<th>LATAMID 66</th>
<th>H2</th>
<th>G/50</th>
<th>METAL REPLACEMENT</th>
<th>LATAMID 66</th>
<th>H2</th>
<th>G/50</th>
<th>LATAMID 66</th>
<th>H2</th>
<th>G/50</th>
<th>METAL REPLACEMENT</th>
</tr>
</thead>
</table>
Special materials
Special materials guide

LATI profile
LATI Thermoplastic industries profile

Products guide
Engineering thermoplastics
flame retardant
high performance

Latilub
Engineering polymers
featuring low coefficient
of friction and high wear
resistance

Metal replacement
Hi-performance compounds,
with high mechanical
properties

Laticonther
Thermally conductive
thermoplastic compounds

Latipro-medical
LATI range for medical
applications

Lati Compounds
For water & food contact

Latigray
Radiopaque thermoplastic
compounds

Latiohm
Electrically conductive
compounds